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Effective predictors of submarine junior officer technical competence

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THESIS

EFFECTIVE PREDICTORS OF SUBMARINE JUNIOR OFFICER TECHNICAL COMPETENCE

by

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June 2003

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This study examines technical and behavioral relationships between independent variables related to U.S. Naval Academy graduates and their probabilities for submarine duty assignment and service with technical competence as junior officers. "Technical competence" is defined as: successful completion of Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination (PNEO). Data analysis of different outcome models is accomplished with the use of binary LOGIT regressions. Results suggest Engineering and Mathematical/Sciences majors (Group 1 & 2) have greater chances for submarine service assignment and better performance during initial nuclear training programs than officers with Humanities/Social Sciences (Group 3) majors. However, the Group 1 & 2 advantages, slowly decrease over time and eventually Group 3 officers linearly perform as well as their peers during PNEO. Findings suggest Group 3 majors are as desirable as other undergraduate majors when selecting submarine officers. Study limitations are discussed with future implications and suggested research opportunities.

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EFFECTIVE PREDICTORS OF SUBMARINE JUNIOR OFFICER TECHNICAL COMPETENCE

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ABSTRACT

This study examines technical and behavioral relationships between independent variables related to U.S. Naval Academy graduates and their probabilities for submarine duty assignment and service with technical competence as junior officers. "Technical competence" is defined as: successful completion of Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination (PNEO). Data analysis of different outcome models is accomplished with the use of binary LOGIT regressions. Results suggest Engineering and Mathematical/Sciences majors (Group 1 & 2) have greater chances for submarine service assignment and better performance during initial nuclear training programs than officers with Humanities/Social Sciences (Group 3) majors. However, the Group 1 & 2 advantages, slowly decrease over time and eventually Group 3 officers linearly perform as well as their peers during PNEO. Findings suggest Group 3 majors are as desirable as other undergraduate majors when selecting submarine officers. Study limitations are discussed with future implications and suggested research opportunities.

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I. INTRODUCTION

A. INTRODUCTION

Recent conflicts in the Middle East have only emphasized the United States Navy's reliance on precision guided weaponry and sophisticated communications networks to provide decisive and victorious outcomes. As the Navy becomes even more technologically advanced, its need for technically-orientated personnel to operate and maintain complex weapons systems will only grow larger. Unfortunately, the amount of technically-skilled people in the civilian population, from which the Navy recruits, has slowly eroded over the past decade. In fact, between 1996 and 2002, the percentage of newly-commissioned Ensigns in the Navy with technical undergraduate majors dropped by over 10%.[1]

Perhaps, no where else is the need for technically-skilled sailors greater than in the nuclear submarine community. Newly-commissioned, submarine officers must endure a rigorous training and qualification program, which starts immediately following their college graduations. In order to successfully reach their first submarine assignments, these officers must display a high level of competency in many academic subjects, such as calculus, physics, and engineering. Historically, the United States Naval Academy has been given the responsibility of providing the majority of these technically-orientated officers to the submarine fleet. As part of this responsibility, the Naval Academy has specifically recruited high school graduates who are technically-inclined and has developed a "core curriculum" designed to provide graduates with a solid technical foundation.

If nothing can be done to stop the decline in a technical recruiting pool, then the Navy must determine how to maintain the submarine force's high levels of technical competence with the currently available accessions. As such, the Navy needs to specifically identify whether tacit knowledge or general knowledge is most important to the successful performance of submarine junior officers.

[1] William Bowman, The Erosion of Technical Skills in Junior Line Officers: A Cause for Concern? Brief to the U.S. Navy Bureau of Personnel. 2002.

B. PURPOSE

The purpose of this study is to examine nine factors related to the personal characteristics of United States Naval Academy midshipmen and evaluate their effectiveness as predictors of submarine junior officer technical competence. "Technical competence" is defined as successfully completing the two components of the nuclear power training pipeline (i.e., Nuclear Power School and Nuclear Power Training Unit) and the Prospective Nuclear Engineer Officer examination. Also, this study will evaluate the validity of the Rickover hypothesis, which posits that the best submarine officers are those characterized by having strong technical backgrounds. This hypothesis has permeated the submarine officer selection process since 1955 when the first naval officer was assigned to command the *USS Nautilus*, the nation's first nuclear submarine.

One of the study's benefits is to provide the United States Naval Academy's submarine community with information regarding which midshipmen are likely to choose the submarine service and perform best during the technical areas of the training pipeline. As a result, the Academy will be able to recruit more midshipmen who are capable of handling the rigors of the nuclear power training pipeline. Secondly, this study will provide those midshipmen desiring a career in nuclear submarines with a model for early success in this community. These midshipmen will then be able to better prepare themselves for submarine duty by developing those characteristics identified in this study which can improve their chances of being service assigned submarines.

During the U.S. Naval Academy's service assignment process, there is a fierce competition among the Navy's various warfare communities (i.e., Surface Warfare, Submarines, Naval Aviation, U.S. Marine Corps, etc.) for the top-rated midshipmen. The top-rated midshipmen are ranked according to their Order of Merit (OOM) scores. The prevailing assumption among the different warfare communities is that the midshipmen ranked highest in the class are the best prepared for service in the fleet as Naval and Marine Corps Officers. However, little research has been performed to validate this assumption. The lack of prior research and the author's desire to benefit his own community led to the development of this study's primary research question.

- *When recruiting midshipmen, what factors should the United States Naval Academy submarine community consider to ensure successful service assignment and technical competence?*

During the literature review, the researcher also developed the following secondary research questions:

- *What factors related to midshipmen performance influence submarine service assignment and technical success?*
- *Do junior officers with Group 1 (Engineering) majors have any advantages over Group 3 (Humanities/Social Sciences) majors in the nuclear submarine community?*
- *What can we tell midshipmen to improve their chances of being selected for submarine service?*
- *Does personal technical interest affect either submarine service assignment or technical success in the submarine community?*
- *What types of non-traditional (i.e., non-engineering majors) students will perform well as junior submarine officers?*
- *Do Academy-related factors, such as RAB scores, have any correlation with Fleet performance?*

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. Scope

This research paper is primarily focused on United States Naval Academy graduates and their technical performance in the submarine fleet. Academy graduates are chosen because, as an academic institution, the Academy is the single largest submarine officer accession source. Over the last ten years, the Academy has provided 33.7% of the new submarine officers in the fleet.[2] As such, the collective effect of Academy graduates on the submarine training program is the largest of any academic institution.

The author's personal interests and familiarity with the submarine community resulted in the exclusion of Surface Warfare Nuclear Officers from this study. These officers also go through Nuclear Power School (NPS) and Nuclear Power Training Unit (NPTU) with future submariners. However, this only occurs after they have first qualified as Surface Warfare Officers on board their surface ships. In addition, the different warfare qualification processes and community emphasis make any performance comparisons of nuclear surface officers to nuclear submarine officers difficult and unreliable.

This study chooses officers who graduated from the Academy between the years 1994 and 1997, because these officers had enough time to complete their initial service obligations, which are approximately five years in length. This initial service obligation allows sufficient time to complete NPS, NPTU (also known as "Prototype"), and the Prospective Nuclear Engineer Officer examination (PNEO).

The U.S. Naval Academy's Office of Institutional Research, Planning, and Assessment maintains the complete and detailed records for all midshipmen from the class of 1990 to the present classes. It is important to note that this study utilizes only complete and verified data. Therefore, midshipmen who have incomplete service histories or who left the submarine community due to medical reasons or inter-service transfers are specifically excluded from this study. As a result, the actual numbers of midshipmen selecting submarines during these class years are slightly different from the numbers reported in the study.

This study focuses on the technical competence of submariners during their initial junior officer submarine tours. Technical competence refers to successfully completing NPS, NPTU, and the PNEO examination. It is used for this study because these parts of the junior officers' career paths are well defined and consistent throughout the fleet. After graduating from their commissioning sources, all submariners have to complete

[2] Data provided via email from the Nuclear Officer Program Manager (N133C). See appendix for more complete accession data.

NPS, NPTU, and Submarine Officer Basic Course before finally reporting to their boats. This is a career progression that has not changed considerably over the past fifty due to the vigilance of Naval Reactors, or the organization in charge of submarine officer development. Naval Reactors has rigidly adhered to the philosophies of its founder, Admiral Hyman G. Rickover, while maintaining the standards of these training programs and instructional courses.[3] In addition, the training and qualification processes on board all submarines are uniform throughout the fleet, regardless of submarine and reactor plant type. Therefore, mitigating factors, such as patrol experience and crew composition, have less of an effect on the junior officer's technical development, than on other professional areas.

Finally, the study does not explore any other professional areas, such as promotion and retention, because it is believed that there are too many possible confounds associated with probability modeling in those areas. For instance, the Navy Fitness Reporting (FITREP) system is still evolving into a more accurate measure of an officer's performance. As such, it is not unusual for an officer to be given a positive FITREP based solely upon promotion concerns and not actual performance. Also, for those officers who resign their commissions, it can be difficult to determine their actual reasons for leaving the Navy, as opposed to what their respective chains of command may require them to list on their resignation letters. In summary, the results of either of these two studies would be difficult to understand or accept as accurate. The current study relies more on academic grades and performance measures collected from the controlled and structured environment of the nuclear power training program. As such, the study's data and findings are less susceptible to dispute.

2. Limitations

Unfortunately, the researcher was unable to obtain the complete technical performance records of every Academy graduate from the classes of 1994 to 1997. Access to these records is restricted by Naval Reactors (NR), which is the organization founded by Admiral Rickover to oversee all submarine-related matters. NR only provides this data to submarine personnel detailers in order to create technically-skilled

[3] Rickover's influence on the Navy's nuclear propulsion programs is discussed further in Chapter 2.

wardrooms for patrolling submarines. Therefore, all data was gathered by the author utilizing methods discussed later in Chapter III of this paper. Had actual grades from Nuclear Power School, Prototype, and the Engineer's examination been obtained, the effectiveness of certain performance predictors could have been greater. Not only could the researcher have been better able to predict if an officer was going to pass or fail a certain school, but he would have been able to predict also the degree of their performance. This information would enhance the understanding of which officers would have few problems in the training pipeline and who should be watched closer for potential academic problems.

Next, because the data was collected from existing and available resources, there was not a complete record for all graduates. Consequently, 36 graduates, or 10.3% of those initially assigned submarines after graduation from the Academy, were excluded from the study. These additional records may have resulted in more accurate models for use as predictors of technical competence and submarine assignment. Also, special cases, such as those graduates who resigned their commissions after their initial service obligations and did not take the Engineer's exam, were difficult to locate and often resulted in that record's omission. The research also only looked at officer performance during their first attempt at passing the Engineer's exam and did not consider subsequent attempts.

Finally, U.S. Naval Academy's Office of Institutional Research, Planning, and Assessment did not start tracking midshipmen preferences for service assignment until 1998. Therefore, it was impossible to determine the differences between those who wanted to serve onboard submarines and those who were actually chosen. It would have been helpful to the submarine community to know which midshipmen were more likely to want submarine service and not just those who were actually chosen. Accordingly, as discussed further in this study, a new recruiting focus and strategy could be developed to target these midshipmen.

3. Assumptions

First of all, it is believed that the best chance of establishing a connection between midshipmen performance and fleet performance existed early in the submarine officer's career path (see Figure 1 for a summary of a typical submarine officer career path). Furthermore, it is assumed that as the officer moved further away from his pre-Academy and Academy experiences, these experiences would have less of an influence on the officer's development. Other variables, such as family planning, health concerns, career advice, positive patrol experiences, etc., may become stronger influences on an officer's performance and career advancement.

Figure 1. Submarine Officer's Career Path by Years of Commissioned Service and Approximate Rank[4]

Next, it is assumed that all midshipmen attending the United States Naval Academy have some minimum degree of technical ability. Technical ability is given a strong consideration by the Admission Board when considering a candidate's application for admission to the Naval Academy. The board specifically reviews a candidate's high

[4] PER42 Website, <http://www.bupers.navy.mil/pers42/pers42opening.htm>.

school grades, math SAT scores, and the Technical Interest Scale scores.[5] These variables are factored into the candidate's Whole Man Multiple score, which is an overall measure of a candidate's application worthiness and is the primary factor considered by the Academy's Admissions Board for acceptance. Furthermore, each midshipman is required to take classes under the Academy's core curriculum, which is designed to provide graduates with a sufficient technical background in order to understand and operate the complex systems onboard ships in the fleet.

Lastly, Naval Reactors has created numerous manuals and instructions covering the training and qualifications of nuclear personnel for use in the submarine fleet. As a result, the training and qualification requirements for the submarines' Engineering Departments are essentially standardized throughout the fleet. Therefore, it is assumed that reactor plant configuration and specific submarine differences are not significant factors with respect to a junior officer's development and that each officer had essentially the same basic nuclear training.

D. ORGANIZATION OF STUDY

This study is organized into six chapters. Chapter I is the introduction necessary to understand the course of study. Chapter II provides the background information needed to understand an Academy graduate's midshipman career, Admiral Hyman G. Rickover's influence on the naval nuclear propulsion program, and the career path of a nuclear submarine junior officer. Chapter III presents some performance theories, and previous studies that have researched the relationship between various midshipmen traits and fleet performance. Chapter IV describes the efforts by the researcher to construct the database, the methodology utilized for this study, and the different variables involved in the outcome modeling. Chapter V reviews the findings of the data analysis techniques and specifically presents the results of the binomial LOGIT regressions for each model. In addition, the model's overall accuracy and classification abilities are discussed.

[5] Technical Interest Scale scores are discussed further in Chapter 4.

Chapter VI presents a summary of the data analysis conclusions, recommends further research related to the subject matter, and provides recommended policy changes based on the study's findings.

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II. BACKGROUND INFORMATION

A. UNITED STATES NAVAL ACADEMY

The mission of the United States Naval Academy has remained largely unchanged since its inception in 1845: "To develop midshipmen morally, mentally, and physically and to imbue them with the highest ideals of duty, honor, and loyalty in order to provide graduates who are dedicated to a career of naval service…."[6] The Academy provides its midshipmen with both a strict military regime and a challenging academic curriculum designed to produce the highest quality naval officers.

1. Entrance Requirements

A typical Academy freshmen class has approximately 1200 midshipmen representing every U.S. state and eight foreign countries. Women make up approximately 15-17% of the class and minorities comprise approximately 20%. Candidates for admission to the U.S. Naval Academy (USNA) must meet the following eligibility requirements listed in the USNA Catalog: have excellent moral character, single, not pregnant, between ages 17-23, medically qualified, scholastically qualified, and receive an appointment from an official nominating source. Official nominating sources include the President, Vice-President, and members of Congress. From the Class of 2006, only 1,457 (11.8%) people out of the 12,333 applicants were offered admission to the Academy and of those offered admission 1,214 (83.3%) accepted.[7]

2. Midshipmen Education

The Academy is a four-year undergraduate college that graduates midshipmen with Bachelors of Science degrees and reserve commissions as officers in the United States Navy or Marine Corps. Each midshipman is required to take classes in engineering, mathematics, sciences, humanities, and social sciences as part of the Academy's core curriculum. The core curriculum is tailored to meet the requirements of a professional naval officer. The midshipmen may also choose to pursue their academic

[6] "Mission of the Unites States Naval Academy," Reefpoints, (Annapolis, MD: 1993) 12.

[7] The entire Class of 2006 Profile is contained in the Appendix.

interest in one of the 20 majors programs offered. These majors programs are divided into the following majors groups: 1) Engineering; 2) Mathematics/Sciences; and 3) Humanities/Social sciences.

In addition to their academic education, midshipmen are required to develop themselves professionally. Formal professional education is taught during required naval leadership and naval science classes, and includes subjects such as the history of the U.S. Navy, seamanship skills, and leadership philosophies. Professional education is further reinforced during summer cruise assignments in the Fleet. Midshipmen are also taught moral education through the Character Development Program. This program consists of philosophy classes, seminars, guest lecturers, midshipmen advisors, and an ethics-based curriculum. The stated goal of the program is "to develop midshipmen who possess a clearer sense of their own moral beliefs and the ability to articulate them."[8] Finally, all midshipmen are expected to live by the Academy's Honor Concept, which simply states "Midshipmen are person of integrity: they stand for that which is right."[9]

3. Service Assignment

During First Class year, midshipmen are assigned service in a warfare community based largely upon their Order of Merit (OOM), which is a cumulative rank that represents all academic, military, and performance grades. All midshipmen list their service assignment preferences and this information is provided to the representatives from the different warfare communities. Next, these representatives review each midshipman's academic, physical, and military performance records before conducting oral interviews. Finally, all additional physical and academic qualifications, such as eyesight and physical readiness test (PRT) scores, are reviewed before a midshipman is assigned duty on Service Assignment Night. Generally, those midshipmen who have attained a higher OOM are more likely to get their first choice of service selection.

This thesis examines the effectiveness of various pre-Academy- and Academy-related factors as predictors of technical competence of recent graduates who were

[8] United States Naval Academy Catalog 2002-2003, (Annapolis, MD: 2002) 2.

[9] United States Naval Academy Catalog 2002-2003, (Annapolis, MD: 2002) 4.

selected for submarine service. Technical competence is defined as successfully completing Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer's examination during the officer's initial service obligation.

B. ADMIRAL HYMAN G. RICKOVER

"And I urge you, in the strongest possible terms, to take a look at that program [naval nuclear propulsion program]...actually look and see what is involved in the technical depth of the organization, because it is there, in the training and education, continuity, and certification of operators, exercises, component testing, quality assurance, all of these items exist and I urge you to study that in some depth…look at an organization which is built on integral engineering and technical competence throughout…."[10]

These were the words spoken by Dr. John Deutsch, the Acting Secretary for Energy Technology for the Department of Energy, to the President's Commission on the Accident at Three Mile Island on April 27, 1979. Deutsch was called to testify before the commission and to present a summary of the roles and responsibilities of the Department of Energy with respect to the regulation of the civilian nuclear power industry. However, Deutsch also wanted to contrast the superb operating record of the Navy's nuclear propulsion program with that of the civilian sector. He firmly believed that the principles and standards adopted by the Navy's nuclear propulsion program, under the leadership of Admiral Hyman G. Rickover, should also be adhered to by the civilian workforce. The result would be an American nuclear power industry that was not only profitable, but also safe. Given this paper's relationship with the Navy's nuclear propulsion program, it seems only fitting to include a discussion of its founder and the "father of the nuclear navy," Admiral Hyman G. Rickover.

Almost every detail concerning the naval nuclear propulsion program can be traced back directly to Rickover. Of the many interesting aspects concerning Rickover's personality, the one that stands out the most is his obsession with obtaining knowledge. Even as an electrical officer onboard his first ship, *USS La Vallete*, Rickover spent

[10] Francis Duncan, Rickover and the Nuclear Navy: the Discipline of Technology (Annapolis: Naval Institute Press, 1990) 273-4.

countless hours studying the engineering plant and neglected all social functions of the wardroom. He believed that it was an officer's duty to master the technical details of every piece of equipment for which he was responsible. This belief persisted throughout his naval career, especially when he created the Navy's nuclear propulsion program. Various maintenance programs, reactor safeguards, operating procedures, plant designs, etc., were all developed with Rickover's approval or urging. When the nuclear propulsion program grew into a more complex and multi-faceted organization, Rickover continued to insist on having final approval in all technical matters relating to the nuclear program. In order to maintain his personal technical competence, Rickover read countless memos, reports, and recommendations from each organization that was involved with the nuclear propulsion program. As a result of his persistent studies, Rickover developed strong and sometimes controversial opinions, which did not always endear him to his many critics. He firmly believed that the best officers, regardless of which warfare community, were those that possessed strong technical backgrounds. Rickover's belief has come to be known as the "Rickover hypothesis" and it has had a profound effect of the selection of submarine officers over the last 48 years. In fact, the "Rickover hypothesis," as applied to the selection and development of nuclear submarine officers, has also caused considerable controversy within the submarine service.

When Rickover was developing the first nuclear powered submarines, he was also considering what type of officers would be needed to command this new, advanced technology. Rickover hypothesized that diesel submarine commanders could not adapt to the demands of nuclear power and that their previous experience would only hinder their development. Instead, Rickover sought to train an entire cadre of officers through schools and programs that he personally developed to mimic the "Rickover Way," or a mastery of nuclear knowledge and thinking. Former Secretary of the Navy John F. Lehman described the "Rickover Way" as follows: "'Do not question higher authority' is raised to the level of purity; all answers are to be found in the book, and the book and the checklist must be followed—a philosophy essential for nuclear safety…."[11] Many diesel submariners tried to resist the submarine force's change towards Rickover's ideology by petitioning the Bureau of Naval Personnel directly for submarine assignment. However,

[11] John Lehman, Command of the Seas (New York: MacMillian, 1988) 21.

as Rickover eventually gained sole control of the submarine personnel assignments, many diesel boat submariners were forced to accept Rickover's changes as they saw their own career paths ended.

C. SUBMARINE OFFICER CAREER PROGRESSION

Every nuclear submarine officer, regardless of his accession source, undergoes the same basic career path mandated by Naval Reactors (NR), the organization Rickover created to oversea the development of nuclear submarines and officers. NR's current mission statement reads: "Naval Reactors is responsible for all naval nuclear propulsion work, beginning with technology development, continuing through reactor operation and, ultimately, reactor plant disposal. The Program ensures the safe operation of reactor plants in operating nuclear-powered submarines and aircraft carriers, and fulfills the Navy's requirements for new nuclear propulsion plants that meet current national defense demands."[12]

Each junior officer must successfully complete an entrance interview process administered by NR, which is designed to assess the applicant's technical ability and fitness for submarine duty. Once accepted, the officer enters the training pipeline, where he receives his initial indoctrination into NR's philosophy and training guidelines. After the training pipeline, which includes power school and prototype, the officer reports onboard a submarine and is required to qualify all watch stations specified in the submarine warfare qualification program. Once qualified as a submarine warfare officer and after serving in a nuclear billet for one year, the officer is eligible to take the Prospective Nuclear Engineer Officer (PNEO) examination. Successfully completing PNEO is a requirement for a submarine officer to continue his career as a Department Head. The career path for a submarine officer graduating from this year's Academy Class of 2003 is provided in Table 1.

[12] FY2003 Congressional Budget (Washington: Government Printing Office, 2002) 5.

Table 1. Career Path for Submarine Officer from the Class of 2003

EVENT	DATE
Interview with Naval Reactors	NOV 02 - JAN 03
Service Assignment	FEB 03
Nuclear Power School	JUN 03 - DEC 03
Nuclear Power Training Unit	JAN 04 - JUN 04
Submarine Officer Basic Course	JUL 04 - OCT 04
Report to Submarine	NOV 04
Qualify Submarines	NOV 05
Prospective Nuclear Engineer Officer Exam	NOV 05 - MAY 08

1. The Entrance Interview

Every nuclear trained officer, beginning with the first Commanding Officer of the *USS Nautilus*, must be personally interviewed by the Director of Naval Reactors prior to his acceptance in the Navy's nuclear propulsion program. The first director, Admiral Rickover, established this policy because he thought, as the Captain of the Navy's "nuclear ship," he was personally responsible to ensure that each candidate was capable of safely operating a nuclear reactor. Rickover achieved this responsibility in the early 1950s, when he convinced then-Chief of the Bureau of Naval Personnel (BUPERS), Admiral James L. Holloway, that the NR director should have the power to personally accept or reject all candidates for nuclear power training before they were assigned by BUPERS.

Rickover would review each candidate's academic and other records prior to the interview, but the interview itself remained an integral part of the selection process. His acceptance criteria consisted of many subjective elements, i.e., age, academic major, etc., that were considered together without a set formula. Rickover said about the interview process: "I talk to a guy…and see how he thinks. I pose questions to him and see how answers them. You don't have to be any superman. If he's the kind of guy that tells you what you want to hear, you kick the guy out of the office after one or two questions."[13] These interviews quickly became part of the Rickover legend as some candidates were locked in closets or forced to sit in purposely uncomfortable chairs while proving their

[13] Lehman, 20.

worthiness. It is estimated that during his career, Rickover personally interviewed fifteen thousand candidates for the nuclear submarine program and rejected more than half of them. Today, the interview may not be as infamous as during the Rickover years, but each successive director has maintained NR's high acceptance criteria.

Before U.S. Naval Academy midshipmen are allowed to go to the entrance interview, their academic, performance, and service assignment interview records are sent to NR for screening. The screeners only allow the highest caliber of midshipmen with the strongest technical backgrounds to attend the interview. According to the current officer in charge of submarine accessions at the Academy, LCDR Scott Fever, NR is typically looking for about 130-140 midshipmen to enter the naval nuclear propulsion program.[14]

The interview process includes two or three interviews with NR staff members that involve discussions of basic engineering and scientific matters. Any identified weaknesses in the candidate's package are examined as well as his ability to respond to different pressure situations. If these technical interviews go well, the candidate is then sent to the director for the final interview where he learns if he has been accepted or not. If accepted, the nuclear training sequence begins with the first part of the training pipeline, Nuclear Power School.

2. Nuclear Power School

The Navy's Nuclear Power School (NPS) is currently located in Charleston, South Carolina. Each officer receives a 24-week course in science and engineering designed "to provide theoretical background knowledge of nuclear power."[15] The course of study includes mathematics, physics, chemistry, thermodynamics, electrical engineering, materials science, reactor dynamics, reactor core characteristics, reactor plant systems, shielding, radiological fundamentals, and reactor plant operations. Officers are required to attend daily lectures and pass written examinations in each subject in order to advance further in the nuclear propulsion program. Those officers

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[14] LCDR Scott Fever. Personal interview. October 2002.

[15] *Submarine Officer*, <www.nrotc.navy.mil/submarineofficer.html>.

who eventually graduate from NPS receive training equivalent to that of an accredited nuclear engineering masters program.[16]

3. Nuclear Power Training Units

The next phase of the pipeline will occur at Nuclear Power Training Unit (NPTU), also known as “Prototype.” Prototypes are located in either Ballston Spa, New York, or Charleston, South Carolina. The only difference between the two prototype locations concerns the nuclear reactor plants found at each location. At Prototype, officers are expected to apply the technical knowledge they acquired at NPS during their qualifications on an operational nuclear reactor plant. Qualifications cover all related primary, secondary, and auxiliary systems contained within the engineering complex. Initially, officers have a month of classroom instruction that covers the basic systems and components installed in their particular reactor plant. During the next five months, officers must qualify at every subordinate watch station in the plant before their final qualification as Engineering Officer of the Watch (EOOW) for that prototype plant. The prototype experience requires officers to perform practical exercises as a demonstration of knowledge and to seek technical interviews from enlisted specialists. Final written and oral examinations that cover complete systems knowledge and watch standing abilities are given to measure individual performance and competence level.

4. Submarine Officer Basic Course

After Prototype, officers report to Submarine Officer Basic Course (SOBC) located at the Naval Submarine Base in Groton, Connecticut. The goal of this twelve-week course is to provide submariners with “an opportunity to learn the theory and principles of submarine operation and control, the basic administrative responsibilities of a division officer, the theory and application of the submerged fire control problem and weapons systems, and the basic fundamentals of submarine operations and tactics.”[17] It should be noted that performance during SOBC is not considered for the purpose of this

[16] *Advanced Engineering in the Navy’s Nuclear Field Program*, <http://www.cnrc.navy.mil/nucfield/college/officer_options.htm>.

[17] *Submarine Officer.*

study because of its focus on basic ship handling, tactics, and other subjects not directly related to nuclear propulsion technical knowledge and ability.

5. Shipboard Qualifications

After SOBC, junior officers report to their submarines and begin an intensive qualification process, which usually takes about a year to complete. A junior officer's qualification plan will encompass all ship's systems and watch stations throughout the boat and culminate with the presentation of the gold dolphins. The gold dolphins, or the submarine warfare insignia, are the oldest warfare pin in the U.S. Navy and symbolize an officer's proficiency in fighting and operating the submarine.

For the first six months onboard, qualifications deal primarily with the reactor plant and other associated auxiliary systems located in the engineering spaces. Junior officers focus on meeting each of the knowledge level and watch standing requirements necessary to qualify as Engineer Officer of the Watch (EOOW) for that submarine's engine room. Although each watch qualification contributes to the officer's overall understanding of the submarine, the EOOW qualification provides the fundamental reactor plant knowledge necessary to eventually qualify for Engineering Duty Officer (EDO) and as Engineer Officer. EDO qualifications occur within months of the EOOW qualifications and EDO watches take place when the reactor is in a shutdown condition. The reactor is normally shutdown in port and required maintenance practices during this condition are often more difficult and require a higher understanding of plant operations in order to maintain reactor safety. Engineer qualifications are discussed later in this chapter and usually occur within a year of EOOW qualifications. EOOW, EDO, and Engineer Officer qualifications form the engineering background and skills required by Naval Reactors for an officer to continue his submarine career.

Consequently, this paper is primarily focused on the requirements for these three qualifications and will neglect discussion of others, such as Officer of the Deck (OOD), which are primarily concerned with tactics and basic ship handling. Junior officer performance in non-technical areas onboard the submarine is not considered for the purpose of this study because of difficulty obtaining common performance data and the effects of various mitigating factors, e.g., patrol schedules, specific plant configurations, and wardroom manning.

6. Prospective Nuclear Engineer Officer Examination

After serving in a nuclear billet for one year and qualifying in submarines, submarine junior officers are eligible to take the Prospective Nuclear Engineer Officer (PNEO) exam. In order for an officer to continue his career in the submarine community as a department head, he must pass this examination and qualify as a nuclear Engineer Officer. Before the examination is actually taken, most submarine officers typically take a PNEO preparation course provided by the particular submarine base's training staff. According to one PNEO course's instructor guide, "the goal of the PNEO course is the achievement of a good understanding of the propulsion plant through a review of basic nuclear propulsion program references."[18] During these courses, officers work mainly in self-study programs, which expand on the knowledge acquired from shipboard qualifications, but there are also several other requirements. That is, all PNEO students must pass in-depth, oral interviews from senior nuclear trained officers as part of their preparation requirements. Next, students must pass extensive written examinations in various subjects, such as plant operations, fluids, reactor theory, electrical engineering, chemistry, and radiological controls. Finally, students are encouraged to review the question banks of previous and frequently asked questions from Naval Reactors personnel.

After completion of the PNEO preparation course, or whenever the Commanding Officer is comfortable with the officer's technical knowledge level, that officer is sent to Naval Reactors (NR) at the Washington Naval Yard in Washington D.C. Once at the NR headquarters, officers are required to undergo a two-day evaluation process consisting of both written and oral examinations. The first day's morning involves at least three, two-hour written examinations, which cover reactor theory and two of the remaining subjects. In the afternoon, NR representatives administer two oral examinations, which cover plant operations and the remaining topics. The second day involves numerous submarine-

[18] Prospective Nuclear Officer Engineer (PNEO) Instructor Guide, (King's Bay Naval Submarine Base , GA, 2002).

related lectures while NR representatives grade all examinations and prepare their recommendations for the director of Naval Reactors, Admiral Bowman.[19] Continuing in the tradition of accountability at NR, Admiral Bowman personally certifies that each officer is qualified to serve on board a submarine as an Engineer Officer.

It is a requirement in the Unites States submarine community that every department head must be qualified as an Engineer Officer. Therefore, in order to continue a career in the nuclear submarine community, an officer must first qualify as an Engineer Officer--otherwise he may be forced to transfer to another community or retire at the end of his obligated service. In contrast, most foreign navies have two basic career paths that an officer may take: engineering and deck duty. Engineers are responsible for the propulsion plant and weapons systems, while deck officers navigate, fight, and command the ship. However, Rickover strongly believed that, if a man knew his job, leadership would follow and he would be strong under the pressures of command. He felt that the only way to understand one's job completely was to master both the technical and strategic aspects of submarining.

D. CHAPTER SUMMARY

This chapter provides the background information necessary to understand how a United States Naval Academy graduate progresses from a midshipman to a nuclear submarine junior officer. Initially, the Academy's application process and required curriculum are explained, followed by the service assignment process. Service assignment is the process by which midshipmen are assigned service in a specific warfare community. Midshipmen who desire submarines are required to pass an interview process with Naval Reactors before they are accepted into submarine community. The history and philosophies of both Naval Reactors and its founder, Admiral Hyman G. Rickover, are also presented in detail.

Finally, a summary of the different programs involved in the training and education of newly commissioned submarine officers is discussed. For the purpose of

[19] Currently, PNEO is slightly different from the process discussed above. Now, officers take the written examinations at their respective submarine bases instead of NR. Those who pass are required to report to NR two weeks later for oral examinations and final results.

this study, the primary focus is on the Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination. This focus is due to the fact that the results from these programs are used in this thesis to define submarine junior officer technical competence, which is one of the things the research is attempting to predict.

III. LITERATURE REVIEW

A. JOB PERFORMANCE THEORIES

As Americans have become more "result oriented," an increasing number of studies have been conducted to determine effective predictors of job performance. Researchers have evaluated job performance by examining the effects of certain factors, such as continuous learning, core knowledge, and experience. Two basic schools of thought have emerged: (1) one that posits that tacit knowledge is essential for superior performance and (2) one that posits that "g," or general knowledge, is the real key to success.

1. Tacit Knowledge

Tacit knowledge is defined as "the practical know-how one needs for success on the job."[20] This knowledge encompasses the inherent abilities and practical intelligence that are not taught, but that are learned through job experience. With respect to this thesis, tacit knowledge would include the experiences and lessons learned from standing watch on an operational reactor plant. Conversely, *g*, or general knowledge, is more academically-based. This knowledge would include the curriculum at USNA, Nuclear Power School, and the Prospective Nuclear Engineer Officer preparation courses.

Research by Steinberg and Wagner suggests that tacit knowledge is a more accurate predictor of job performance than *g* for multiple reasons. First of all, tacit knowledge is better at solving practical problems found in most jobs because ill-defined problems often require multiple acceptable solutions, which are not found as a result of formulas or theorems. Only though personal motivation and related experiences are solutions developed. The *g* intelligence is more useful for academic problems where the information required is given and there is usually one correct answer. Tacit knowledge is better suited to the work place because it is experimentally learned through observations, watching norms, and analyzing different options. Conversely, the *g* knowledge is more structured and learned primarily through reading and studying.

[20] Robert J. Steinberg and Richard K. Wagner, "The g-ocentric View of Intelligence and Job Performance Is Wrong." Current Directions in Psychological Science 1993, 2.

Tacit knowledge has many critics, however, who believe that it is a puzzling and unproven concept. These critics acknowledge that although tacit knowledge may be used in addition to general intelligence for predicting job performance, there may not be enough research to sufficiently support this argument. Researcher, Arthur Jensen, writes, "Obviously, we will need to know much more empirically about the nature of tacit knowledge for it to become a theoretically coherent and convincing psychological construct."[21] Researchers, such as Jensen, prefer the use of general knowledge when predicting job performance.

2. General Knowledge

The idea of *g*, or general knowledge/intelligence/ability, as a predictor of performance has been more widely studied and accepted than tacit knowledge. *g* differs from tacit knowledge because it is affected by academically learned content, which results from both experiences and abilities. Tests that measure *g* intelligence, such as IQ tests, Stanford-Binet, and the Armed Services Vocational Aptitude Battery tests, have been shown to accurately predict job performance.[22,23] Some researchers claim that the correlation between *g* and job performance is so high that it alone can be used for employee selection with favorable results. Similar findings from studies suggest that when subjects in a study have equal levels of experience (e.g., USNA graduates), then the correlation between intelligence and job knowledge (i.e., performance) is at its maximum.[24]

B. RELATED STUDIES

Job performance studies have also examined military personnel. Some studies have focused on using cognitive abilities and academic majors as predictors of USNA graduates' performance in the fleet, while others, such as Leskovich, have examined non-

[21] Arthur R. Jensen, "Test Validity: *g* Versus 'Tacit Knowledge,'" Current Directions in Psychological Science. (February 1993).

[22] Malcolm James Ree and James A. Earles, "Intelligence is the Best Predictor of Job Performance," Current Directions in Psychological Science. (June 1992).

[23] Nathan Brody, "Intelligence, Schooling, and Society," American Psychologist. (October 1997).

[24] Steinberg and Wagner, 8.

cognitive abilities.[25,26,27,28] His study focused on collegiate varsity athletics at USNA and found that there were slight increases in promotion rates for heavily recruited (or "blue chip"), intercollegiate varsity, and club sports athletes. However, this study was confounded by the fact that a high percentage of midshipmen were secondary school athletes. Essentially, all midshipmen were high school varsity athletes and had to pass a physical fitness test as part of the application process. Therefore, the differences in athletic ability between a Varsity athlete and the average midshipman are negligible.

Conversely, there is overwhelming evidence to suggest that cognitive abilities are accurate predictors of fleet performance. In a recent thesis by Reardon, he claims that the admission and professional development processes have a direct impact on "the high level of performance and retention of USNA graduates."[29] Performance had been measured in terms of promotion rates and retention over twenty years of service. His focus was on the "Whole Man Multiple," which is a sum qualification score given to every USNA applicant and is determined by weighting aspects of high school performance. Reardon found that the "Whole Man Multiple," heavily favors mathematical ability and secondary school rank. Both of these measures of cognitive skills are good predictors of graduation probability at USNA. Reardon concluded from his research that all midshipmen have some basic technical abilities and the Academy's core curriculum provides the foundation for future success as officers.

Bowman studied USNA graduate performance as junior officers in both the surface and submarine warfare communities. Graduates were classified as either engineering/technical majors or others. Successful submarine career performance was measured by factors including recommendations for early promotion and rank in the top one percent for specific fitness report (FITREP) categories. Bowman's conclusion was

[25] Matthew G. Reardon, The Development of Career Naval Officers from the U.S. Naval Academy: A Statistical Analysis of the Effects of Selectivity and Human Capital. (Naval Postgraduate School, CA: June 1997).

[26] William R. Bowman, "Do Engineers Make Better Naval Officers?" Armed Forces and Society. (Winter 1990).

[27] Eric P. Woelper, The Impacts of Academic Background on Submariner Performance, Retention, and Promotion. (Naval Postgraduate School, CA: June 2000).

[28] John R. Leskovich, The Impact of Athletic Achievement at the United States Naval Academy on Fleet Performance. (Naval Postgraduate School, CA: June 2000).

[29] Reardon, V.

that "even the non-accredited engineering/science majors are as likely to achieve superior performance as are the technically oriented accredited engineering and math/physical sciences majors."[30]

Woelper provided further evidence regarding the predictive value of academic performance. He specifically examined submarine officer performance with respect to the following four areas: completing the nuclear power training pipeline, early promotion, retention beyond ten years, and promotion to Lieutenant Commander. He concluded that officers who had engineering undergraduate majors and high grade point averages outperformed their peers in all areas. His overall recommendation to the submarine community was to continue to rely on high grades and engineering majors as the primary means for service assignment. However, his study looked at all accession sources and not just the U.S. Naval Academy, which is the largest single submarine accession source and has a required technical curriculum. As a result, he may not have seen the value of USNA non-technical majors who by the admissions screening process and the USNA curriculum have a higher technical ability than other colleges' non-technical majors. Also, his study stopped at the end of the training pipeline, or the completion of Nuclear Power Training Unit. Therefore, he may not have realized the importance of the tacit knowledge, which submarine officers gain from the fleet's training and qualification programs, to the improvement of their technical performance.

This thesis examines the degrees of behavioral relationships between independent variables related to U.S. Naval Academy graduates and their probabilities of submarine service assignment and technical competence as junior officers. Technical competence is defined as successful completion of Nuclear Power School, Nuclear Power Training Unit, and the Prospective Engineer Officer examination (PNEO). In a community such as submarines that is driven by technology, would engineer majors and those with better academic grades still excel? What other variables are statistically significant predictors of technical competence?

[30] Bowman, Do Engineers, 281.

C. CHAPTER SUMMARY

The theoretical basis of this study lies in understanding the two basic theories related to job performance--tacit knowledge and general knowledge. Tacit knowledge stresses the importance of on the job training and "common sense" solutions to difficult problems. Conversely, general knowledge emphasizes the learned knowledge that a person receives from academic or training environments as the key to high performance. This thesis attempts to determine which of these theories is more important to the development of a junior officer's technical competence.

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IV. RESEARCH METHODOLOGY

A. DATABASE DESCRIPTION

This research paper originally intended to look at the actual grade point averages received by student officers during their attendance at Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination. Actual grade point averages would have been helpful in explaining not only if an officer completed the training, but also how well or poorly they performed. Models could have been used to determine those students, who are borderline performers and barely pass or fail. These identified officers could be targeted at the Academy for extra instruction in Nuclear Power School-related subjects. As it turned out, it was not possible to obtain actual officer records from Naval Reactors for this study. This information is considered classified and is only used by submarine community detailers at the Bureau of Naval Personnel (BUPERS) for submarine manning purposes. Consequently, it was necessary to construct an original database from the existing available sources listed in Table 2.

Table 2. Summary of Available Data Sources

Data source	**Types of data provided**
Institutional Research	graduates service assigned subs; independent variables
U.S. Naval Active Duty Register	officer career paths; dependent variables
Defense Manpower Data Center/ BUPERS	officer career paths; dependent variables
Undersea Warfare magazine	officer career paths; dependent variables
Augmentation Board/ PNEO instructors/USNA Alumni Registry	officer career paths; dependent variables

Every midshipman from classes 1994 to 1997 who was initially assigned submarine service was identified. This information was obtained from the Office of Institutional Research, Planning, and Assessment (IR) at the U.S. Naval Academy. The office was created in 1992 for the purpose of "evaluating and disseminating institutional data to stimulate positive changes to the admissions and education processes at the

United States Naval Academy."[31] IR maintains full academic and performance records on every midshipmen beginning with the class of 1990. These records provide the study with the majority of the independent variables used in model construction and the names of all graduates initially accepted into the nuclear power program. IR data indicates that 351 total midshipmen were service assigned submarines between 1994 and 1997 (see Figure 2).

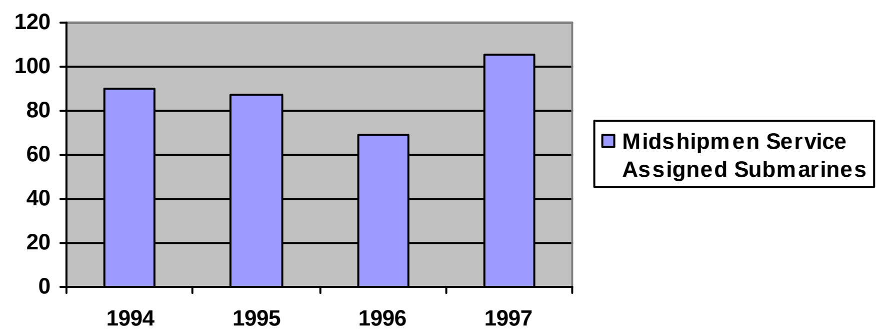

Figure 2. All Midshipmen Initially Service Assigned Submarines from USNA Classes 1994-1997

The next step identifies the actual career paths of these midshipmen, in order to determine how far through the submarine training pipeline and/or the Engineer's exam an officer progresses. Career path information is essential to determine the accuracy of any performance models developed in the study. In order to most accurately determine the officers' career paths, a number of independent sources are utilized and all information is cross-checked against each other.

The first source used is the U.S. Naval Active Duty Register NAVPERS 15018.[32] BUPERS maintains this publication and it lists the full name, year group, and designator of every active duty officer in the navy. Every service community in the Navy, e.g., surface warfare, SEALs, etc., has a specific designator associated with it. Active-duty,

[31] *USNA Office of Institutional Research, Planning, and Assessment*, <http://www.usna.edu/IR/>.

[32] *U.S. Navy Active Duty Register*, <https://buperscd.technology.navy.mil/bup_updt/upd_CD/BUPERS/Register/ActiveMenu.htm>.

submarine officers from USNA are initially designated 1170 and once they qualify as submarine warfare officers are given the designator 1120.[33] Reserve, submarine officers from USNA are initially designated 1175 and once they qualify as submarine warfare officers are given the designator 1125. Submarine officers will retain the 1120/1125 designator for the length of their service as long they pass the Prospective Nuclear Engineer Officer examination (PNEO) and qualify as nuclear engineers. Each submarine officer is also required to pass PNEO before he can extend his service obligation beyond the initial service obligation of five years. All of the year groups used in the study had their initial service obligations expire by the time the register was updated on 06 September 2002. Therefore, if the officer had stayed in the Navy beyond his initial service obligation, and his designator was known, the researcher could deduce that the officer had in fact passed PNEO and the training pipeline.

The next two data sources are taken from the Defense Manpower Data Center (DMDC) and the Submarine Community Manager at BUPERS. Both of these databases contain similar information with respect to the duty history and status of submarine personnel. DMDC, originally called the Manpower Research and Data Analysis Center (MARDAC), was established in 1974 as a Department of Defense (DoD) activity within the Navy. Later it was renamed DMDC and transferred to the Defense Logistics Agency (DLA) and designated a Defense Support Activity supported by DLA. DMDC's mission is to "collect and maintain an archive of automated manpower, personnel, training, and financial databases for the Department of Defense, support the information requirements of the OUSD (P&R) and other members of the DoD manpower, personnel, and training communities with accurate, timely, and consistent data.…"[34] The DMDC and Submarine Community databases contain significant personnel information, such as commissioning sources, duty station histories, date of resignation of commission, and rank and designator at time of resignation. Since an officer has to complete Nuclear Power School (NPS) and Prototype to make it to a submarine, it is possible to use this information to know who has passed these career milestones.

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33 NAVPERS 15839I- Navy Officer Manpower and Classification, Part A.

34 *Defense Manpower Data Center (DMDC)*, <http://www.dmdc.osd.mil/>.

At this point, the database still has some incomplete information. Frequently, it is known that a particular graduate entered the nuclear power program, but not how far he has progressed. The submarine community publishes a professional quarterly magazine titled *Undersea Warfare*. This magazine has a section called *Downlink* and is used to congratulate those officers who qualified in submarines or nuclear engineer officer. Since an officer has to complete NPS and Prototype prior to qualifying in submarines, the study was able to determine the graduates' progress through the nuclear power training pipeline. It is next assumed that, if a graduate shows up on the Qualified Engineer's List, then he has passed the exam. As such, *Undersea Warfare* is an excellent source of graduate information and is used to verify other data sources.

The last attempt to retrieve submarine officer data utilizes the following three data sources: November 2002 Augmentation Selection Board results, PNEO instructors from Bangor and Kings Bay Naval Submarine Bases, and the USNA Alumni Registry. Upon graduation, officers from the class of 1997 were initially given reserve officer commissions instead of active duty commissions. The major difference in the commission types was that reserve officers can be asked to leave the Navy at any time without receiving severance pay. However, in November 2002, the Navy Augmentation Board convened and voted to augment all commissions to active duty for the class of 1997. The message sent to the fleet included the officer's name, last four digits of their social security number (SSN), and their old and new designators. After verifying the name and SSN, the study determines the officer's designator and is able to deduce other career information. Next, the PNEO instructors have pass/fail data for students most recently enrolled in their courses. This data not only provides missing PNEO information, but also clarifies who had taken the exam twice. Finally, when all other data sources are used, it is possible to track down the missing data by finding the officers' email addresses on the USNA Alumni Registry and contacting them directly. The email request includes a short synopsis of the thesis project and asks respondents for a short narrative of their own and specific classmates' career paths. Approximately eighty percent of the seventy people contacted responded with the requested information.

In the end, the study has missing information on 36 of the total 351 USNA graduates, who were initially service assigned submarines between the class years of

1994 and 1997 (see Table 3 and Figure 3). Since the database only excludes approximately 10% of the total officers initially assigned submarines, the missing information is considered negligible and the analysis sample is assumed to be representative of the general population.

Table 3. Thesis Database Statistics

	1994	1995	1996	1997	Total
Officers Service Assigned Subs	90	87	69	105	351
Officers with Valid Data	79	75	67	94	315
Valid Percentage	**87.8**	**86.2**	**97.1**	**89.5**	**89.7**

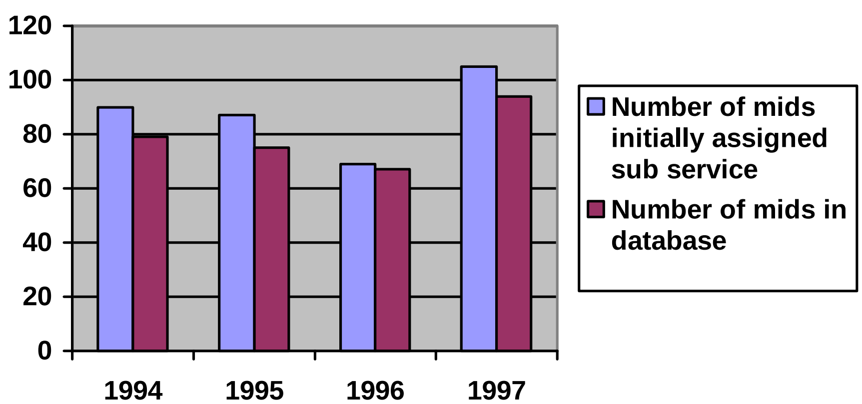


Figure 3. Midshipmen Representation in the Database

B. METHODOLOGY

Most social scientists prefer to use linear regressions to explain the various behavioral relationships among observed outcomes on a continuous scale. However, for linear regressions to accurately predict the effects on a dependent variable for a small unit change of an independent variable, the dependent variables must be continuous. Otherwise, it is nearly impossible to estimate the standard errors associated with each of the regression coefficients and if they significantly differ from zero. In this study, the dependent variables have only dichotomous, or binary outcomes--officers either are assigned submarine service or not, and either pass a particular training program or not.

Therefore, a more complex, non-linear procedure is required to transform each dichotomous outcome into a continuous, bounded zero to one-hundred percent probability of occurrence. Ultimately, a binary logistic (LOGIT) regression is chosen for this study.

Binary LOGIT regressions use a standard logistic density function to transform the dichotomous dependent variables into a new random variable with continuous properties. One such transformation is the logistic distribution function, denoted by:[35]

$$P_i = E[Y_i|X_i] = \frac{e^{b_0 + b_1 X_{1,i}}}{1 + e^{b_0 + b_1 X_{1,i}}}$$

Where e (=2.718) is the base of natural logarithms. The above equation can be rewritten into the Probability Distribution Function (PDF) form as:

$$P = \frac{e^{Z_i}}{1 + e^{Z_i}} = \frac{1}{1 + e^{-Z_i}} \qquad \text{where } Z_i = b_0 + b_1 X_{1,i}$$

While not proven here it can be shown that the two characteristics of a probability density function are satisfied with the above formula. It can also be shown that:

$$P(Y = 0) = 1 - P(Y = 1) = 1 - P_i = \frac{1}{1 + e^{Z_i}}$$

Then the dependent variable is transformed into an "odds ratio" as:

$$\frac{P_i}{1 - P_i} = \frac{\left(\frac{e^{Z_i}}{1 + e^{Z_i}}\right)}{\left(\frac{1}{1 + e^{Z_i}}\right)} = e^{Z_i} = e^{b_0 + b_1 X_{1,i}}$$

The "odds ratio" shows the ratio of the probability of success (Yi = 1) to the probability of failure (Yi = 0). Next, we take the natural log of the "odds ratio.

$$L_i = \ln\left(e^{b_0 + b_1 X_{1,i}}\right) = b_0 + b_1 X_{1,i}$$

[35] William Bowman, Dichotomous Dependent Variables and Regression Analysis Using SPSS. (Annapolis: USNA, 1998) 5-6.

The result is that the log of the "odds ratio" of Y=1 is now a *linear* function of the independent variables, X_k. The linear function can be analyzed further using more traditional solution methods.

When trying to understand LOGIT regression models, it is important to note three basic characteristics.[36] First, the probability of a successful event occurring (P(Y=1)) is bounded and goes from 0 to 1, while the logit (L_i) is unbounded between $-\infty$ and Z_i (see Appendix for figure of the Cumulative logistic Density Function (CDF)). Second, the log likelihood ratio is linear in terms of X, but the probability that Y=1 is not linear. Thus the researcher needs to know both the value of the estimators and the level of the probability from which the change is made. Third, the estimated slope coefficients are difficult to interpret because they represent the impact of changes of independent variable on the logarithm of the "odds ratio" and not the dependent variable itself. In order to see the independent variables' effects on the dependent variables, the slope coefficients must be converted to LOGIT marginal effects.

This research uses the following method to calculate LOGIT marginal effects as outlined in Bowman's "Dichotomous Dependent Variables and Regression Analysis Using SPSS."[37]

1. Calculate $Z = \sum b_k * Xbar_k$
   Where: b_k = LOGIT coefficient for independent variable "k"
   $Xbar_k$ = intercept and mean values of independent variables.
2. Calculate $P(Y=1) = 1 / (1 + e^{-Z})$
3. Calculate $P(Y=0) = 1 - P(Y=1)$
4. Calculate "delta" (the marginal effect)
   "marginal effect" = $b_k * (P * (1 - P))$.

36 Bowman, Dichotomous, 7.

37 Bowman, Dichotomous, 14.

When evaluating a non-linear model such as a binary LOGIT regression, one must remember that the marginal effects of a single independent variable will vary over the range of values for each of the remaining variables. This is in contrast to linear models where the marginal effect of a single independent variable is constant regardless of the other variables' different values. It is the interdependency of the non-linear model which allows it to more accurately represent complex relationships than linear models.

1. Dependent Variables

Three related variables are used to develop the actual dependent variables chosen for modeling in this research paper. These related variables include:

- NPS, which represents the completion of Nuclear Power School (NPS). Successful completion is indicated as a '1' outcome while failure is a '0' outcome.
- NPTU, which represents the completion of Nuclear Power Training Unit (NPTU). Successful completion is indicated as a '1' outcome while failure is a '0' outcome.
- PNEO, which represents the completion of the Prospective Nuclear Engineer Officer (PNEO) examination. Successful completion is indicated as a '1' outcome while failure is a '0' outcome.

Together, these variables represent the successful completion of the three major phases of technical performance during a submarine junior officer's initial service obligation.

The first dependent variable chosen for analysis is ASSIGNSU and it represents the acceptance of midshipmen into the nuclear propulsion program by Naval Reactors (NR). As previously discussed in this paper, midshipmen submarine candidates are initially chosen by the members of the submarine community at the U.S. Naval Academy to interview with Naval Reactors personnel. After the interviews are completed, NR personnel forward their recommendations to the Director of Naval Reactors. The director makes the final decision regarding acceptance into the nuclear propulsion program. ASSIGNSU represents this ultimate decision by the director.

The next dependent variable is COMP2 and it represents the officer's success at both Nuclear Power School (NPS) and Nuclear Power Training Unit (NPTU). It includes officers who graduated from the U.S. Naval Academy between 1994 and 1997 and were initially accepted by NR into the nuclear power program. NPS and NPTU are the major components of the nuclear power training program and are usually completed within fourteen months of graduation from the Academy.

The last dependent variable used for modeling is COMPALL3 and it is representative of a submarine junior officer's overall technical abilities during his initial service obligation. It includes successful performance during the nuclear power training pipeline and the Prospective Nuclear Engineer Officer examination (PNEO). PNEO is the culmination of all technical knowledge that a junior officer has received during college, the training pipeline, and shipboard training and qualification programs. The knowledge also has both tacit and general components. A description of each dependent variable is provided in Table 4.

Table 4. Description of Dependent Variables

Variable	**Description**	**Mean value**
ASSIGNSU	Represents midshipmen acceptance status into nuclear power program = 1 if midshipman accepted = 0 if midshipman not accepted	0.10
COMP2	Represents if officer successfully completed NPS *and* NPTU = 1 if officer completed successfully = 0 if officer did not complete successfully	0.92
COMPALL3	Represents if officer successfully completed NPS, NPTU, *and* PNEO = 1 if officer completed successfully = 0 if officer did not complete successfully	0.99

The ASSIGNSU model includes 3214 total midshipmen (N = 3214) in its analysis. These 3214 midshipmen represent the entire male population from classes 1994 to 1997 who are assigned service in a warfare community and graduate on time with their classmates. Of these 3214 midshipmen, 315 (9.8%) are assigned submarine service. Female midshipmen are excluded from the study because they are not eligible for submarine service. The COMP2 model considers the 315 male midshipmen (N = 315) who are initially service assigned submarine duty, are medically fit for submarine service, and report to Nuclear Power School (NPS). Of these 315 midshipmen, 291 (92.4%) passed both NPS and Nuclear Power Training Unit (NPTU). Midshipmen who are medically disqualified or transfer warfare communities before NPS or NPTU are excluded from the analysis. Finally, the COMPALL3 studies the 291 midshipmen (N = 291) graduating from both NPS and NPTU and meet the prerequisites to take the Prospective Nuclear Engineer Officer (PNEO) examination. The prerequisites are to be submarine qualified and to serve in a nuclear division officer billet for one year or have a waiver from Naval Reactors. Of the 291 officers, 287 (98.6%) passed the PNEO exam. Those officers who fail out of the training pipeline, do not qualify submarines, or decline to continue their naval careers are not considered for model analysis.

2. Independent Variables

a. Pre-Academy Experience

The methodology utilized during the selection of the independent variables is based upon the theory that an officer's performance during the initial training pipeline is based upon both his pre-Academy and Academy technical experiences. Pre-Academy experiences refer to high school performance and admissions application data. A summary of pre-Academy, independent variables is provided in Table 5 below.

Table 5. Summary of Pre-Academy Independent Variables and Expected Effects

Variable	Description	Expected Effect on Technical Performance	Mean Value of entire male pop.
SATM 0 to 800	Score from math section of SAT or ACT (ACT score translated to SAT scale).	positive	661.3
SATV 0 to 800	Score from verbal section of SAT or ACT (ACT score translated to SAT scale).	positive	636.3
RAB500 -3000 to 10000	Recommendation of the Admissions Board (RAB) These are additional points that are added to the admission applicant's Whole Man Multiple score, or the measure of an admission's package strength. RABs are an attempt by the board to more fairly represent an applicant's potential success at the U.S. Naval Academy. Are awarded in increments of +/- 500 points.	negative	3.1
CIS 0 to 800	Career Interest Scale raw score calculated from the Strong Interest Survey. Indicates an admissions applicant's interest in making the U.S. Navy a career.	positive	504.4
TIS 0 to 800	Technical Interest Scale raw score calculated from the Strong Interest Survey. Indicates an admissions applicant's interest in technical subjects.	positive	502.2

The first independent variables discussed are SATM and SATV. Since each high school has different educational focuses and curricula, high school grades were deemed too subjective for use in this study. Therefore, the only high school academic performance data used was Scholastic Aptitude Test (SAT) scores and American College Test (ACT) scores that are rescaled to reflect SAT scores. While many colleges consider other factors for admissions, during the period of observation most colleges weighted SAT and ACT scores heavily into the admissions process. It is assumed that those officers with higher SAT scores have greater cognitive abilities and will perform better during the technical aspects of submarine training.

There are many variables that are specific to the Naval Academy's admissions process. Of these variables, only three were considered for this study. First, the Recommended by the Admissions Board (RAB) score is the number of bonus points awarded to or subtracted from an applicant’s package to present a more accurate portrayal of their potential success at the Naval Academy. RAB scores are given in sets of 500 points and are officially awarded for the following reasons: [38]

- Outstanding ratings in Blue and Gold Interview Overall Evaluation. Academy representatives, known as Blue and Gold Officers, conduct interviews with admissions’ candidates and access their midshipmen potential.
- Candidates who are legacies.
- Candidates who graduate from a high school where at least 65% or more of students go on to a four-year college.
- Special circumstances.
- Candidates who achieved a specific score on the Physical Aptitude Evaluation.
- Those who participated in USNA Summer Seminar programs.
- Other circumstances that require adjustments to the candidate’s multiple to reflect their motivation and potential for success at USNA.

The last reason for a RAB score, to improve a candidate’s multiple to better reflect his or her motivation, is a frequent reason given to justify RAB awards. Since these candidates generally have weaker admissions’ packages and academic credentials, the initial assumption is that those midshipmen with higher RAB scores will be less likely to do well in the nuclear propulsion program. One reason RAB is selected for this study, is it is more indicative of a candidate’s motivation and potential then other admissions factors. Another reason for selection is that the RAB is a single score and not an aggregate value, such as the Whole Man Multiple, which is composed of many

[38] *USNA Admissions*, <http://www.usna.edu/AboutAIS.>.

different variables. Therefore, the effects of only the RAB can be directly observed and not obscured by multiple component variables.

Next, applicants to the Naval Academy are required to take the Strong Interest Inventory self-administered survey. This questionnaire is used to determine the applicants' interests in the following three areas: career retention, engineering sciences, and humanities/social sciences. Career retention and engineering science are used to calculate Career Interest Scale (CIS) scores and Technical Interest Scale (TIS) scores respectfully. CIS and TIS are the only scores from the Strong Inventory Interest test used in the calculation of the Whole Man Multiple, or the overall measure of candidate's strength used for admissions purposes by the board. CIS is used because it is indicative of a midshipman's interest to make the Navy a career. If someone already sees the Navy as a career they are more apt to enjoy their experiences and perform well in the fleet. The initial assumption is that the higher the CIS, the more likely the officer will complete the different phases of nuclear training during his initial service obligation. TIS is selected because the submarine community is extremely technically orientated. Submarine enlisted sailors are initially identified by high Armed Services Vocational Aptitude Battery (ASVAB) test scores and academic performance in order to select those best suited to understand the technology involved in submarine operations. It is assumed that those officers with higher technical interests will perform better in the training pipeline and during the Engineer's exam. A summary of the pre-Academy expected effects is provided in Table 5. The expected outcomes are indicated as either positive or negative and are in reference to the expected correlation with technical performance in the submarine fleet. For example, an officer who had high SAT Math scores is expected to pass Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination.

b. Academy Experience

In this study it is assumed that the Academy experience will have the largest impact on an officer's technical performance because of the short time period between graduation and the start of the nuclear power training pipeline. Conversely, as an officer progresses further in his career and takes the Engineer's examination, the

Academy experience would have less and less of an effect. Instead, service and personal factors, such as personal service experiences, the length of patrols, marital and family issues, and the like, would have more of an influence on success.

The first independent variable from the Academy experience is GROUP and it refers to the one of the three majors groups the officer chooses from while at the Academy (see Table 8 for complete list of the currently offered majors programs). All midshipmen at the Naval Academy are required to take a core curriculum of classes, which provides a sufficient technical background for a future naval officer. However, this study assumes that those officers who are Group 1 or 2 majors will enjoy even greater success in the nuclear propulsion program due to their extra technical training. In addition, these officers have already shown a strong interest in technology-related disciplines and, presumably, would be more likely to perform better in the highly-technical, nuclear submarine community as a result.

Table 6. Currently Available Majors at the U.S. Naval Academy

Group Majors		
I- Engineering	**II- Mathematics/Sciences**	**III- Humanities/Social Sciences**
Aeronautical Eng.	Chemistry	Economics
Astronautical Eng.	Computer Science	English
Electrical Eng.	General Science	History
General Eng.	Information Technology	Political Science
Mechanical Eng.	Mathematics	
Naval Architecture	Oceanography	
Ocean Engineering	Physics	
Systems Eng.	Quantitative Economics	

The next independent variables are indicative of academic and military performance. Initially, Order of Merit (OOM) was considered for the analysis. OOM is the Naval Academy's overall midshipmen ranking criteria. However, OOM is an aggregate score and the study found it to be more beneficial to evaluate its components and determine their individual significance rather than to look at OOM as a whole. Therefore, each of the three OOM components, according to the U.S. Naval Academy's academic instruction USNAINST1531.51A, is identified as an initial basis for modeling.

The three basic components are Academic and Professional Courses, Physical Education, and Military Performance. Next, the literature review identifies which of the measures used to compute the three OOM components are possible performance predictors. These measures are listed below:

- CUM_AQPR (cumulative academic quality point rating)
- TECH_QPR (technical courses quality point rating)
- CORE_QPR (core curriculum quality point rating)
- CUM_MQPR (cumulative military performance quality point rating)
- MAJOR_QPR (major courses quality point rating).

Next, initial regressions are performed to access the degree of multi-collinearity. From this analysis, it is determined that CUM_AQPR and MAJOR_QPR are too highly correlated with TECH_QPR in the same model specification. Because TECH_QPR is more significant to the analysis outcomes in both cases, it is selected for the study. A summary of Academy-related independent variables and their expected outcomes is provided in Table 7. The expected outcomes are indicated as either positive or negative and are in reference to the expected correlation with technical performance in the submarine fleet. For example, an officer who is a Group 1 major is expected to pass Nuclear Power School, Nuclear Power Training Unit, and the Prospective Nuclear Engineer Officer examination.

Table 7. Summary of Academy Independent Variables and Expected Effects

Variable	Description	Expected Effect on Technical Performance	Mean Value of entire male pop.
GROUP	USNA Majors Group		
1	Engineering Majors	positive	0.41
2	Mathematics/Sciences Majors	positive	0.24
3	Humanities/Social Sciences Majors	negative	0.35
GRAD_YEA			
1994	Graduated in 1994	no effect expected	0.25
1995	Graduated in 1995	no effect expected	0.25
1996	Graduated in 1996	no effect expected	0.25
1997	Graduated in 1997	no effect expected	0.25
TECH_QPR 0.0 to 4.0	Average quality point rating of the Science and Engineering courses which are essentially common to all majors.	positive	2.70
CUM_MQPR 0.0 to 4.0	Midshipman's cumulative military quality point rating of the 8 total semesters at the Naval Academy.	positive	3.24
MAJOR_QPR 0.0 to 4.0	Average quality point rating of required courses in the midshipman's selected major.	positive	2.97

Finally, the remaining variables in the database provide the personal information on the officers in the study. This personal information is used to identify those midshipmen who were initially service-assigned submarines. It also provides the characteristics used to cross-check information from the various data sources used in the construction of the final database. A summary of the variables related to personal information is provided in Table 8.

Table 8. Summary of Variables Related to Personnel Information

Variable	Description
NAME	Name of the Officer
MID_ID	Six-number, identification code given to all midshipmen The first two numbers represent class year and the remaining numbers are sequentially assigned in alphabetical order.
SERV_ASS	Community initially assigned to the officer
AEROMAINTD	Aerospace Maintenance Duty Officer
CEC	Civil Engineering Corps
CRYPTO	Cryptology
FN	Foreign Navy
INTEL	Intelligence
IST	Information Systems Technology
MEDICAL	Medical Corps
NFO	Naval Flight Officer
NPQ	Not Physically Qualified
NUC SUB	Nuclear Submarines
NUCSURF	Nuclear Surface Navy
OCEANOGRAP	Oceanography
PILOT	Naval Aviation (Fixed and Rotary Wing)
SPECOPS	Special Operations
SPECWAR	Special Warfare (SEALs)
SUPPLY	Supply Corps
SWO	Surface Warfare
UNKNOWN	Unknown
USMC GROUN	Marine Corps Ground Forces
USMC NFO	Marine Corps Flight Officer
USMC PILOT	Marine Corps Aviation (Fixed and Rotary Wing)
DESIG	Four-number, officer designator code for corresponding service community

C. CHAPTER SUMMARY

This chapter explains the various sources utilized to construct the study's database. A database had to be constructed because there was not a single data source, which contained all the required information for the study. Therefore, multiple sources were used to provide the required midshipmen performance and officer technical competence data needed for analysis.

A binary LOGIT regression is chosen as the primary analytical tool used to establish any relationships between the independent and dependent variables. Binary LOGIT regressions are more complex, non-linear procedures that are able to transform each dichotomous outcome into a continuous, bounded zero to one-hundred percent probability of occurrence. Explanations of binary LOGIT characteristics and the method used to transform the dichotomous outcomes into continuous probabilities are also provided.

Finally, a summary is presented of how the dependent and independent variables used for modeling are selected. All dependent and independent variables are selected only after reviewing related studies and the researcher's personal submarine experiences. Dependent variables are separated into three models representing submarine service assignment and nuclear power training program performance. Independent variables are initially divided into pre-Academy and Academy-related variable groups. Then independent variables are further tested for collinearity and certain, highly-correlated variables are eliminated from the modeling before the final selection is complete.

V. DATA ANALYSIS

A. INTRODUCTION

This chapter contains that results of the various analytical procedures utilized during the study. The results are divided into different sections, which represent the thesis' two major areas of focus. The first section focuses on the submarine service assignment portion of a U.S. Naval Academy graduate's career. This section presents the analysis results of the pre-Academy and Academy variable groups separately. The results are presented in the following manner:

- Binary LOGIT regression results
- Marginal effects
- Overall model accuracy and classification ability

The second section focuses on the Navy's nuclear propulsion training program. This research is further sub-divided into two different models—the nuclear power training pipeline and the Engineer Officer's examination. The training pipeline model is only concerned with an officer's performance at both the Nuclear Power School (NPS) and Nuclear Power Training Unit (NPTU), which the officer attends immediately following graduation from the Academy. The other model focuses on the officer's performance during the Prospective Nuclear Engineer Officer (PNEO) examination taken at the end of the initial service obligation. The second section's data analysis results are presented in a similar manner as in the first section.[39]

B. RESULTS

The study's major findings are the high correlation between majors group and overall technical course grades with being assigned submarine service and succeeding in the training pipeline, i.e., NPS and NPTU. Specifically, Group 1 majors (Engineering)

[39] In this chapter, there is no discussion of the analysis results from all models using a combination of pre-Academy and Academy independent variables. These results can be reviewed in the Appendix. Also, pre-Academy independent variables were excluded from the analysis of the successful completion of NPS and NPTU (COMP2) model and the successful completion of NPS, NPTU, and PNEO (COMPALL3) model. None of these variables were found to be statistically significant in either model and the increases in classification abilities were minimal.

have higher probabilities of being assigned submarines and passing NPS and NPTU than other majors groups. And those midshipmen who graduated with higher technical grades have greater probabilities of submarine service and training pipeline success. The COMPALL3 model, which predicts passing NPS, NPTU, and the PNEO exam, does not establish any behavioral relationships between the independent variables and the dependent variable, or outcome. Instead, the model's outcome is as likely due to chance than to a behavioral relationship among the variables. However, the probability of Group 3 majors (Humanities/Social Sciences) performing well at this point in their careers is just as good, if not better, than other majors groups. Both the training pipeline and the shipboard training and qualifications programs appear to improve the technical abilities of the Group 3 officers to the level of their peers. Lastly, only 4 out of 291 officers, who graduated USNA, failed the Engineer's exam. This high success rate is indicative of the effectiveness of the training and qualification programs in the submarine fleet, which prepare junior officers for the PNEO exam.

1. Submarine Service Assignment (ASSIGNSU) Model

The first model is concerned with submarine service assignment. Midshipmen are accepted into the submarine service after passing a series of interviews with the USNA submarine community and Naval Reactors personnel (see Chapter 2 for a more detailed description of the service assignment process). The research attempts to develop a model that most accurately predicts which types of midshipmen are initially accepted into the nuclear propulsion program. The belief is that once these midshipmen types are known, any possible weaknesses of the current submarine recruitment efforts and selection process can be identified. The research can also identify for midshipmen interested in submarine service, the performance factors that are shown to have the most influence on submarine assignment.

This research primarily relies on binary LOGIT regressions in order to predict the dichotomous outcomes for all the models examined. The binary LOGIT converts the two possible outcomes for the ASSIGNSU model, assigned or not assigned submarine service, into an outcome which is continuous and bounded by a zero to one-hundred percent probability of occurrence. As stated previously, regressions are designed to estimate the behavioral relationships between a set of independent and dependent variables. The first binary LOGIT regression uses the variables associated with an officer's pre-Academy experience as the independent variables. These variables are SAT math scores (SATM), SAT verbal scores (SATV), RAB scores awarded by the admissions board (RAB500), Career Inventory Scale scores (CIS), Technical Inventory Scale scores (TIS), and year of graduation (GRADYEA). The results of the binary LOGIT regressions and marginal effects are presented below in Table 9.

Table 9. Submarine Service Assignment Model LOGIT Results for Pre-Academy Variables

SUBMARINE SERVICE ASSIGNMENT MODEL			
pre-Academy Variables			
independent variables	**LOGIT**	**Significance**	**Marginal Effect**
constant	-10.727	**0.000**	**-0.6745**
SAT Math (per 100 pts)	0.800	**0.000**	**0.0503**
SAT Verbal (per 100 pts)	0.400	**0.001**	**0.0251**
RAB500	-0.061	**0.007**	**-0.0038**
Career Inventory Score	0.001	0.193	0.0001
Technical Inventory Score	0.000	0.688	0.0000
Class of 1994	-0.084	0.629	-0.0053
Class of 1995	0.117	0.481	0.0074
Class of 1996	-0.244	0.171	-0.0153

***- bold indicates significant**

The regression results reveal that three of the independent variables associated with the pre-Academy experience, i.e., SATM, SATV, and RAB500, are statistically significant. This means that there is at least a 95% certainty that the observed relationships between the independent and dependent variables are due to a behavioral relationship rather than to chance. For the purpose of this study, statistically significant variables have significance values (i.e., p-values) that are less than or equal to 0.05. The binary LOGIT regression confirms the existence of a relationship between SATM, SATV, and RAB500 and the probability of being assigned submarine service.

The marginal effects calculations for the pre-Academy variables reveal many interesting findings.[40] First of all, for every 100 points higher on the SAT math section that the average midshipmen scores, he improves his chances of submarine service assignment by approximately 5%. The average midshipmen who scores 100 points higher on the SAT verbal section has an approximately 2.5% improved chance of submarine assignment. Both of these SAT results coincide with the expected effects predicted in Chapter 3. Higher SAT math scores are indicative of higher technical abilities, while higher SAT verbal scores are associated with general academic and learning abilities. Both SAT math and verbal scores represent a person's *g*, or general knowledge, level. It is also interesting to note that higher math SAT score is estimated to have twice the impact on nuclear submarine service selection than the verbal SAT score. This is comparable to the relative weights given to math and verbal SAT scores in the calculation of a Naval Academy applicant's Whole Man Multiple index. This index is used to rate the strength of a person's application and it gives twice the weight to SAT math scores as it does to verbal scores.

The submarine service assignment model also suggests that applicants given higher added bonus points to their Whole Man Multiple index are less likely to be selected for submarine service. The RAB500 variable, which represents the increments of 500 bonus points awarded to Naval Academy applicants in order to better represent the applicants' potential at the Academy, is negatively correlated with submarine service assignment. However, the value of the RAB500's estimated impact on submarine assignment is almost negligible. For every 500 point RAB, the average midshipman is only 0.3% less likely to be assigned submarines.

Finally, the TIS score is designed to give greater weight to applicants most likely to choose technical majors and desire service in technical warfare communities, i.e., submarines. However, the study shows that TIS has no significant effect on submarine service assignment. Therefore, the TIS score is not effective at measuring a midshipman's technical inclination leading to submarine service assignment.

[40] The full marginal effects tables can be seen in the Appendix.

The next regression attempts to estimate any behavioral relationships between Academy experience variables and submarine service assignment. The results of this regression and marginal effects are provided below in Table 10.

Table 10. Submarine Service Assignment Model LOGIT Results for Academy Variables

SUBMARINE SERVICE ASSIGNMENT MODEL			
Academy Variables			
independent variables	**LOGIT**	**Significance**	**Marginal Effect**
constant	-6.598	**0.000**	**-0.5146**
Group 1	1.599	**0.000**	**0.1247**
Group 2	0.911	**0.000**	**0.0711**
Technical QPR	1.227	**0.000**	**0.0957**
Cumulative Military QPR	-0.672	**0.031**	**0.0524**
Major QPR	0.652	**0.001**	**0.0509**
Class of 1994	-0.158	0.389	-0.0123
Class of 1995	-0.030	0.866	-0.0023
Class of 1996	-0.464	**0.014**	**-0.0362**

***- bold indicates significant**

This second regression shows that six independent variables related to the Academy experience are statistically significant. These variables are engineering majors groups (GROUP1), mathematics and sciences majors groups (GROUP2), common technical course overall grade (TECH_QPR), cumulative military performance grades (CUM_MQPR), majors' courses overall grades (MAJOR_QPR), and the Class of 1996 (GRAD_YEA3). Once again, the study establishes a behavioral relationship between the Academy variables and the probability of submarine assignment.

The estimated marginal effects for many of the Academy variables reveal statistically significant relationships between submarine service assignment and the Academy experience.[41] First of all, the midshipman's majors group has a substantial effect on submarine assignment. A midshipman who is a Group 1 or 2 major consistently has a better chance of submarine assignment then a Group 3 major. Figure 4 represents

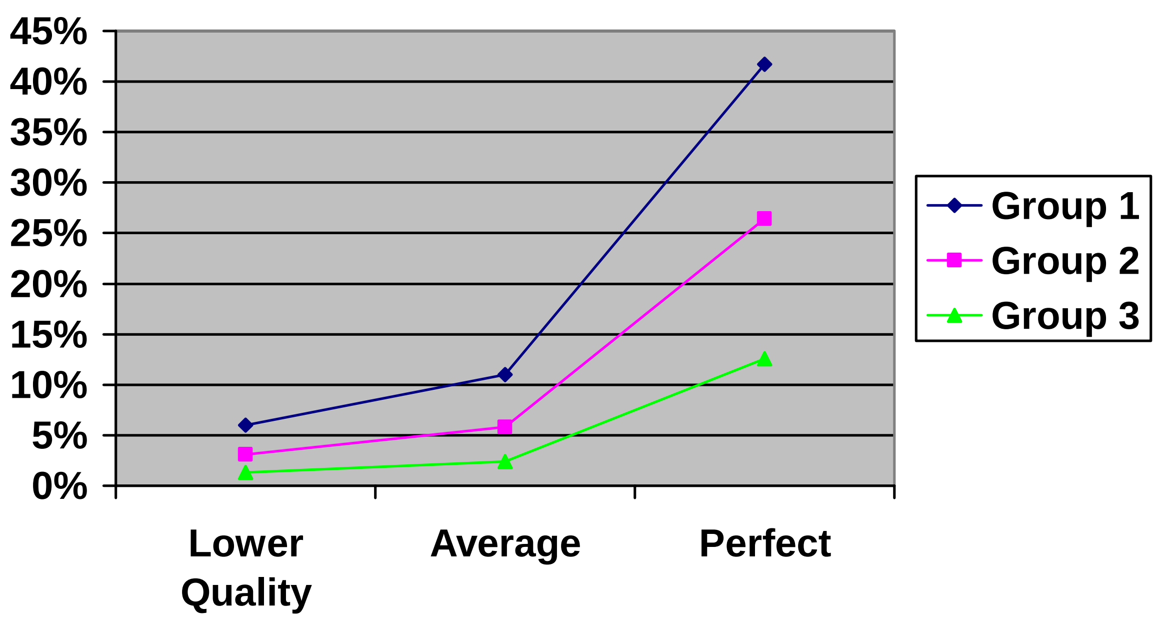
41 The full marginal effects tables can be seen in the Appendix.

the different probabilities of submarine assignment for all the majors groups for three different types of midshipmen. The first midshipmen type is the lower quality midshipman, having a 2.0 quality point ratings for technical courses, cumulative military grades, and major's courses. The second midshipman is the average midshipman and has the average scores recorded for the entire male midshipmen population that graduated between the years 1994-1997. Finally, the "perfect" midshipman has 4.0 quality point ratings for technical courses, cumulative military grades, and major's courses. Table 11 summarizes the characteristics of each midshipmen type considered in the analysis.

Table 11. Characteristics of Midshipmen Types

Midshipmen Type	TECH_QPR	CUM_MQPR	MAJOR_QPR
Lower Quality Mid.	2.00	2.00	2.00
Average Midshipman	2.70	3.24	2.97
Perfect Midshipman	4.00	4.00	4.00

Figure 4. Submarine Assignment Probabilities by Major



The non-linear shape of the line graphs shown in Figure 4 suggests many important findings. First, the choice of academic major has a greater impact on being chosen for submarines as a person becomes a better student. For example, a Group 1 *average* midshipman has only a 9% better chance of submarine service than a Group 3 *average* midshipman (11% versus 2%). But a Group 1 *perfect* midshipman has 28% better chance (43% versus 13%). In other words, the estimated impact of academic majors on submarine service selection increases nearly three fold for a midshipman with perfect scores than one with average scores.

Another finding from Figure 4 is that a p*erfect* midshipman majoring in Group 3 has roughly the same chance of submarine assignment as the *average* Group 1. When the student observed is better, the success probability differences between majors tripled. This suggests that the best quality of Group 3 midshipmen may not feel comfortable with their chances of submarine service or with their overall impressions of submarine life. For a summary of the submarine service assignment differences among the different majors groups see Table 12.

The high positive correlation between majors group and selection for submarine service is expected given Naval Reactors' history. Since its inception, Naval Reactors has maintained a faithful allegiance to many "Rickover-isms," including the "Rickover hypothesis," which states that technical graduates make better naval officers. Therefore, it is not surprising that technical majors (Group 1 and 2) have a higher probability for submarine selection by Naval Reactors. It is clear that midshipmen who want to better their chances for submarine service should consider Group 1 or 2 undergraduate majors.

The line graphs also show that the average Group 1 midshipman has almost the same probability of being assigned submarines as the perfect Group 3 midshipman. This finding further stresses the importance of major selection to midshipmen desiring submarine service. Finally, the overall increase in submarine service assignment probabilities as the quality of midshipman improves, suggests that as a midshipman becomes a better student, he may feel more comfortable with submarine service and desire such this assignment. This effect may be the result of the high caliber of sailors and officers within this warfare community.

Table 12. Submarine Service Assignment Differences Among Majors Groups

	Probability Differences
Lower Quality Midshipmen	
α_0	5%
β_0	2%
Average Midshipmen	
α_1	9%
β_1	4%
Perfect Midshipmen	
α_2	28%
β_2	13%
note: α_x is the difference between Group 1 and Group3 β_x is the difference between Group 2 and Group3	

The next Academy-related independent variable that shows a significant relationship with submarine assignment is TECH_QPR. For every 1.0 point a midshipman improves his technical courses overall quality point ratings, it is predicted that he has a 9.6% better chance of being selected for submarines. Again, this significant relationship between TECH_QPR and submarine assignment is expected due to Naval Reactors' technical emphasis. And the significance of doing well in the technical core courses and being selected for submarines, regardless of major selection, is only underscored.

Given that the TECH_QPR and the quality point rating in one's majors courses are already specified in the model, the cumulative military quality point rating is negatively related to submarine assignment. For every 1.0 point a Midshipman improves his CUM_MQPR, he is estimated to have a 5.2% less chance of being selected for submarines. This finding is surprising, considering that one of the goals of the United States Naval Academy's Midshipmen Military Performance Grade System is "to identify those midshipmen who possess outstanding officer-like qualities and are best qualified to occupy positions of authority and responsibility in the Brigade."[42] Therefore, the initial

[42] COMDTMIDNINST 1600.2A- Midshipmen Military Performance System, 2.

assumption was that higher military performance grades would result in better selection chances. One possible reason for the actual negative correlation is that weaker academically performing midshipmen try to offset their lower academic grades by trying harder in other areas, such as military performance. Conversely, “smarter” midshipmen expend most of their efforts maintaining their high academic grades, which are the largest component of the Order of Merit calculation. Since, Naval Reactors uses grades as one of its primary acceptance criteria, midshipmen chosen for submarine service because of these better grades will also tend to have the slightly lower military performance grades.

Finally, being a member of the Class of 1996 would have given a midshipman a lower probability (-3.6%) of being assigned submarines. Looking at the descriptive data chart provided in the appendix, it is apparent that the lowest number of midshipmen recruited at USNA for submarine service occurred in 1996. In fact, 27 less midshipmen were accepted in 1996 than in 1997, which was the reference group for the study’s analysis. Historical analysis also shows that the total number of new submariners for all accession sources during 1996 was one of lowest in 20 years (see Figure 6). The possible accession sources are the United States Naval Academy, Naval Reserve Officer Training Commands (NROTC), Nuclear Enlisted Commissioning Program (NECP), and the Nuclear Propulsion Officer Candidate Program (NUPOC). Together, these phenomena help to explain the negative correlation of the class of 1996 with the submarine service assignment (ASSIGNSU) model.

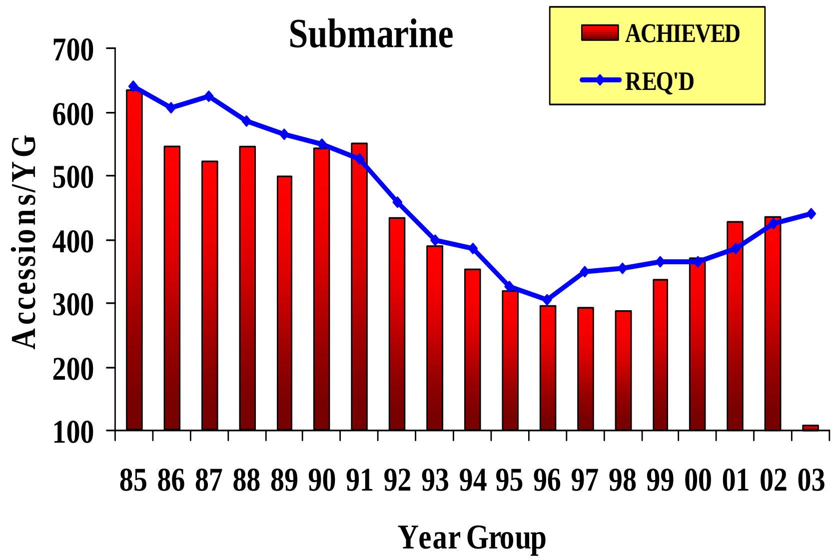


Figure 5. Total Submarine Accessions[43]

Lastly, the submarine service assignment (ASSIGNSU) model's overall accuracy and classification abilities are analyzed. From the entire male midshipmen population (3214 midshipmen) from USNA classes 1994 to 1997, only 315 midshipmen (9.8%) were initially assigned submarine service.[44] When discussing the accuracy of non-linear models such as ASSIGNSU, Bowman writes, "…it remains difficult to agree on a single statistic that best measures errors from actual outcomes that have only two values—and these values are at the very extremes of the transformed probabilities of an event occurring."[45] This research focuses on the Chi-square statistic and the classification table results to describe the model's accuracy and predictive abilities. A summary of the submarine service assignment model is provided below in Table 13.

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43 *PERS42 Website*, <http://www.bupers.navy.mil/pers42/pers42opening.htm>.

44 Actually, 351 midshipmen were initially assigned submarine, but complete data could only be gathered for 315 of these midshipmen.

45 Bowman, Dichotomous, 26.

Table 13. Submarine Service Assignment Model Summary

Submarine Service Assignment Model		
	pre-Academy variables	Academy variables
Summary Data	**Value**	**Value**
Chi^2 model	152.075	355.564
significance	0.000	0.000
degrees of freedom	8	8
Classification		
% O correct	64.1	71.8
% 1 correct	63.8	73.7
% total correct	64.1	72.0
-2 log likelihood	1909.292	1705.803
Nagelkerke R^2	0.098	0.221

First of all, the ASSIGNSU model's Chi-square values (152.075 and 355.564) and significance values indicate that the independent variables as a group are statistically significant ($p<0.05$). In addition, the model correctly classified over 60% (pre-Academy) and 70% (Academy) of each assignment outcome, which is particularly strong since only 10.9% of the sample were actually assigned submarine service.

The classification analysis uses a cutoff frequency, or the observed average of the dependent variable, of 0.10 for the submarine service assignment model. Those cases with predicted values above the cutoff frequency are classified as positive, while those with predicted values smaller than the cutoff are classified as negative. The submarine service assignment model, using only pre-Academy variables, accurately predicts, or classifies, those midshipmen assigned submarines 63.8% of the time. This model also correctly predicts those *not* assigned submarines 64.1% of the time for an overall accuracy total of 64.1%. The submarine service assignment model using only Academy variables is even more accurate and correctly predicts those midshipmen assigned submarines 73.7% of the time. This model also correctly predicts those *not* assigned submarines 71.8% of the time for an overall accuracy total of 72.0%. In summary, both of the ASSIGNSU model groups can correctly predict submarine service assignments greater than half the time.

2. Successful Completion of NPS and NPTU (COMP2) Model

After the officer's initial service assignment into the submarine community, the research focuses on the training aspects of the nuclear propulsion program. The length of time between when the independent variables are collected and when the dependent variables, or outcomes, occur directly affects the model's accuracy. The larger the time difference, the more likely confounds, or unanticipated errors, are introduced into the model. Therefore, when modeling the various training aspects of the nuclear propulsion program, the research neglects the pre-Academy variables entirely and focuses only on Academy related variables.

For the purpose of this study, an officer's initial nuclear training is broken into two separate areas—the nuclear power training pipeline and the nuclear Engineer's examination. Because the nuclear power training pipeline, i.e., Nuclear Power School (NPS) and Nuclear Power Training Unit (NPTU), occur within a year and a half of graduating the Academy, the initial assumption is that Academy factors would have the most effect on the completion of those two training programs. Conversely, because the Prospective Nuclear Engineer Officer's exam occurs anytime from two-and-a-half to five years after graduation from USNA, it is assumed that Academy experience would have the least effect on its successful completion.

The model, COMP2, attempts to predict those officers who will successfully complete both NPS and NPTU. Together, these training programs indoctrinate newly commissioned officers into the theoretical background and fundamental concepts of nuclear power and the engineering qualification process. Because a dichotomous outcome is predicted, the appropriate analytical technique is a binary LOGIT regression. The regression results and marginal effects are presented below in Table 14.

Table 14. Successful Completion of NPS and NPTU Model LOGIT Results for Academy Variables

Successful Completion of NPS and NPTU Model			
Academy variables			
independent variables	**LOGIT**	**Significance**	**Marginal Effect**
constant	-3.005	0.403	-0.1551
Group 1	1.179	**0.055**	**0.0593**
Group 2	0.146	0.825	0.0073
Technical QPR	1.490	**0.012**	**0.0750**
Cumulative Military QPR	-0.221	0.845	-0.0111
Major QPR	0.227	0.685	0.0114
Class of 1994	-0.310	0.608	-0.0156
Class of 1995	0.258	0.671	0.0130
Class of 1996	1.054	0.218	0.0530

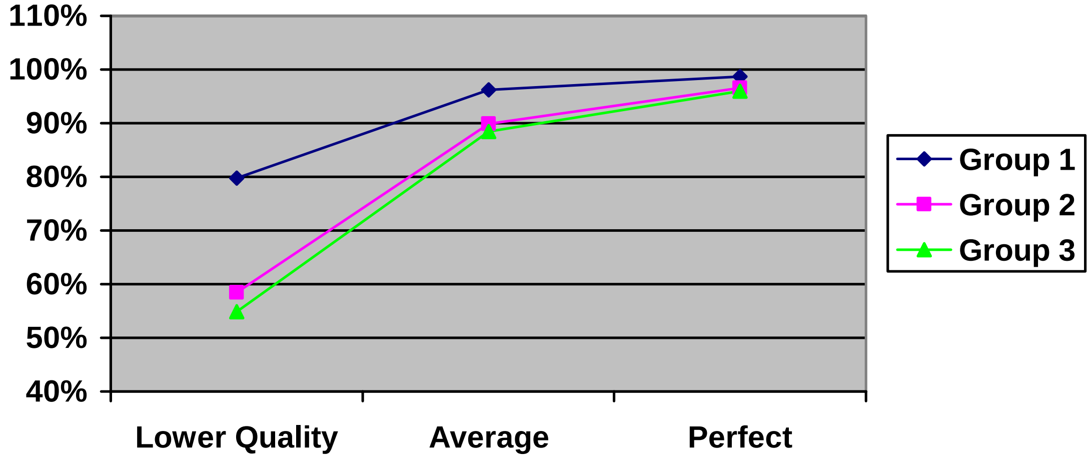
***- bold indicates significant**

The regression is run on a subset of Academy graduates who both desire and are assigned submarine service (N=315). The regression results indicate only two of the Academy-related independent variables are statistically significant, engineering majors (GROUP1) and technical courses' grades (TECH_QPR).[46] Both of these independent variables are statistically significant and disprove the null hypothesis to indicate a behavioral relationship in completing NPS and NPTU programs.

Marginal effect calculations for the COMP2 model, or completing NPS and NPTU, indicate a strong positive relationship with the GROUP1 variable. Officers who are Group 1 majors consistently have higher probabilities of completing the NPS and NPTU programs. Figure 6 represents the different probabilities of successful completion of NPS and NPTU for all the majors groups for three different types of midshipmen. Once again, the midshipmen types are lower quality, average, and perfect. However, this time the average midshipman is comprised of the average characteristics of the 315 midshipmen initially service assigned submarines between the years 1994 and 1997.

[46] Even though the GROUP1 variable is slightly greater than 0.05, it is still within the expected accuracy range of the analysis.

Figure 6. Successful Completion Probabilities of NPS and NPTU by Major



The non-linear line graphs of Figure 6 illustrate some interesting findings. First, is the clear advantage that Group 1 midshipmen have over other group majors during NPS and NPTU. This advantage is greatest among the *lower quality* midshipmen where engineer majors have a 22-25% better chance of passing NPS and NPTU as compared to other majors groups. However, as the quality of student increases, the advantage of Group 1 majors over other majors gradually decreases. It is noted that Group 1 *average* midshipmen have only a 6% better chance of passing NPS and NPTU than Group 2 majors. And Group 1 *perfect* midshipmen have only a 2% better chance. These findings would suggest that the greatest risks for failure during the submarine training pipeline are the *lower quality*, Group 2 and 3 majors.

Figure 6 shows the overall decreasing probability gap between engineering majors (Group 1) and humanities/social sciences majors (Group 3). However, it also shows that the probability differences between the mathematics/sciences majors (Group 2) and Group 3 is almost negligible. It is suspected that the common disadvantage among Group 2 and 3 majors is the lack of *g*, or general knowledge, with respect to engineering subjects. These students have to work harder at NPS and NPTU in order to re-familiarize themselves with complex engineering concepts and theories. This is especially surprising regarding Group 2 majors who are technically proficient in mathematics, chemistry, and physics. It is clear, that if a midshipman wants to better his probability of successfully completing NPS and NPTU, he should consider a Group 1 major.

Finally, Figure 6 shows that Naval Reactors may not always want to select Group 1 majors over Group 2 and 3 majors. The *average* group 2 and 3 majors have greater probabilities of success in these programs than the *lower quality* Group 1 majors (90/89% to 80% respectively). The *perfect* group 2 and 3 majors have even better probability differences with *low quality* group 1 majors (97/96% to 80% respectively).

The other Academy-related independent variable that shows a strong relationship with successful completion of Nuclear Power School and Nuclear Power Training Unit is TECH_QPR. For every 1.0 point a midshipman improves his technical courses overall quality point ratings, he has a 7.5% better chance of successfully completing NPS and NPTU. This high positive association between TECH_QPR and COMP2 is expected because it is assumed that a midshipman who performs well in technical classes better understands the technical theories and concepts than his peers. This midshipman has already built the solid technical foundation needed to succeed during the submarine training pipeline. This finding also substantiates that knowledge acquired in a technical core set of courses, in addition to the individual characteristics of those selecting a technical major, results in greater probabilities of success in the nuclear power training pipeline.

Lastly, the successful completion of NPS and NPTU (COMP2) model's overall accuracy and classification abilities are analyzed. From those male midshipmen (315 midshipmen) initially selected for submarine service, 291 (92.4%) of them successfully completed NPS and NPTU. Once again, this research is primarily concerned with the Chi-square statistic and the classification table results to describe the model's accuracy and predictive abilities. A summary of the COMP2 model is provided below in Table 15.

Table 15. Successful Completion of NPS and NPTU Model Summary Data

Summary Data	Value
Chi^2 model	18.957
significance	0.015
degrees of freedom	8
Classification	
% O correct	70.8
% 1 correct	67.4
% total correct	67.6
-2 log likelihood	150.743
Nagelkerke R^2	0.140

The COMP2 model's Chi-square value (18.957) indicates that the independent variables as a group are statistically significant ($p<0.05$). The successful completion of NPS and NPTU model's classification analysis uses a cutoff frequency of 0.92 and reveals an overall correct classification of 67.6%. Specifically, the model's value is shown in its ability to accurately predict NPS and NPTU failures 70.8% of the time. This high accuracy percentage is a vast improvement over the failure accuracy percentage achieved by pure chance, which is only 7.6%. The model is also able to predict successful NPS and NPTU completions 67.4% of the time. Both the Chi-square and classification table statistics indicate a model, which accurately predicts outcomes greater than 50% of the time.

3. Successful Completion of NPS, NPTU, and PNEO (COMPALL3) Model

The last training model predicts which officers will successfully complete both training pipeline programs and the Prospective Nuclear Engineer Officer (PNEO) exam. The PNEO exam is a comprehensive oral and written examination covering multiple subjects related to nuclear power, such as plant operations, fluids, reactor theory, electrical engineering, chemistry, and radiological controls. Once an officer passes the PNEO exam, he is qualified as a nuclear Engineer Officer and may continue his career in the submarine service as a department head. The regression is run on a subset of

Academy graduates who successfully completed NPS and NPTU and were eligible to take the PNEO exam (N=291). Of these 291 USNA graduates, only four (1.4%) failed the exam. The regression results and marginal effects for the COMPALL3 model are presented below in Table 16.

Table 16. Successful Completion of NPS, NPTU, and PNEO Model LOGIT Results for Academy Variables

Successful Completion of NPS, NPTU, and PNEO Model			
Academy variables			
independent variables	**LOGIT**	**Significance**	**Marginal Effect**
constant	12.874	0.896	0.0087
Group 1	-7.853	0.926	-0.0047
Group 2	-8.710	0.918	-0.0057
Technical QPR	-0.749	0.627	-0.0010
Cumulative Military QPR	2.096	0.411	0.0014
Major QPR	0.805	0.543	0.0009
Class of 1994	-8.153	0.871	-0.0056
Class of 1995	-7.936	0.875	-0.0053
Class of 1996	-7.755	0.878	-0.0054

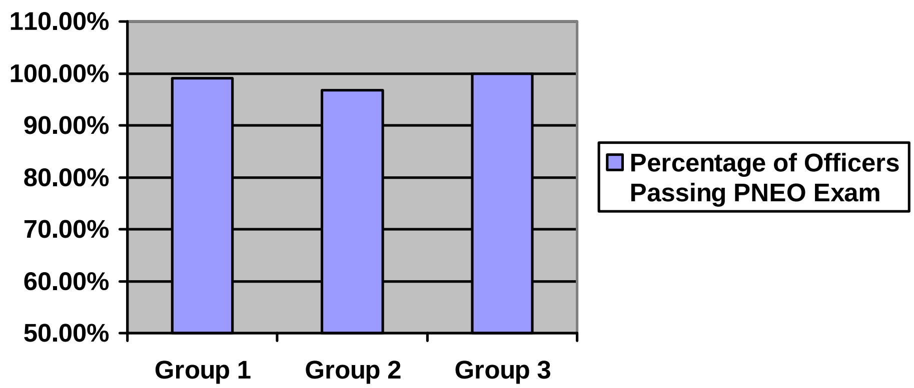
***- bold indicates significant**

There are no independent variables that are statistically significant for the COMPALL3 model. Therefore, the null hypothesis is correct and it is possible that any relationships between the independent and dependent variables are due to pure chance. One possible explanation for the lack of any statistically significant variables is that too much time has transpired between the Academy experiences and taking the PNEO exam. This time lapse has allowed multiple confounds, such as patrol lengths, career aspirations, and family matters, to enter the analysis and introduce error. These confounds may have more effect on passing PNEO than the variables selected for this study. Another possibility is that the nuclear submarine officer selection process results in a highly homogeneous group of officers, who were selected by Naval Reactors, and who then completed a rigorous training and qualification program. Those selected are so similar that is it difficult to extract any statistically significant variables from the model.

The last possibility is that it is extremely difficult to predict a failure outcome that occurs only 1.4% of the time. This small percentage makes any highly accurate prediction expectations unreasonable.

According to the COMPALL3 model, the average officer out of the 291 total officers who successfully completed the training pipeline has a very high probability (99.9%) of passing the Engineer's exam. The high probability of success correlates well with the actual results from the PNEO exam. Two hundred eighty seven officers (98.6%) out of the two hundred ninety-one taking the Engineer's exam passed. The actual PNEO results from the studied population are shown in Figure 7.

Figure 7. Actual Observed Percentages of Officers Passing PNEO Exam



Interestingly enough, the early advantages that Group 1 and 2 majors appear to have during service assignment and completing NPS and NPTU disappear during the PNEO exam. In fact, Group 3 majors, who make it to the exam, have a slightly higher probability of passing than the other majors groups. This finding suggests that the high caliber of the training and qualification programs that a submarine junior officer experiences during the training pipeline and on board the submarine, does an excellent job of preparing him for the Engineer's exam. Furthermore, the training and qualification programs are effective regardless of the officer's academic background. Using these findings, the USNA submarine community can take the average characteristics of the Group 3 officers, who passed PNEO, and develop initial selection criteria for recruiting

Group 3 midshipmen. Submarine community representatives can then contact midshipmen early in their Academy careers for possible submarine service and try to increase their interest. This recruiting tactic would be beneficial to the submarine community's retention efforts because these Group 3 midshipmen can not only make it through the training pipeline, but also become eligible to continue their careers as department heads after passing the PNEO exam. An independent samples t-test performed on the successful Group 3 characteristic variables reveals that only RAB500 and TECH_QPR are statistically significant. See Table 17 for the successful Group 3 selection criteria as compared to the average Group 3 male midshipman graduating between the classes of 1994 and 1997.

Table 17. Group 3 Midshipmen Characteristics Comparison

Variable	Average Group 3 Midshipman	Average "Successful" Group 3 Midshipman
SATM	639.8	679.6
SATV	636.2	684.8
RAB500	4.29	2.44
Technical QPR	2.43	3.16
Cum Military QPR	2.18	3.33
Major QPR	2.97	3.36

Lastly, the successful completion of NPS, NPTU, and PNEO (COMPALL3) model's overall accuracy and classification abilities are analyzed. Again, this research is primarily concerned with the Chi-square statistic and the classification table results to describe the model's accuracy and predictive abilities. A summary of the COMPALL3 model is provided below in Table 18.

Table 18. Successful Completion of NPS, NPTU, and PNEO Model Summary

Summary Data	Value
Chi^2 model	6.024
significance	0.645
degrees of freedom	8
Classification	
% O correct	75.0
% 1 correct	55.7
% total correct	56.0
-2 log likelihood	36.217
Nagelkerke R^2	0.152

The COMPALL3 model's Chi-square value (6.024) and significance value indicate that the independent variables as a group are not statistically significant ($p>0.05$). The model does not capture any behavioral relationships between the independent and dependent variables and is essentially no better than chance when predicting outcomes. The COMPALL3 classification analysis uses a cutoff frequency of 0.99 and reveals an overall correct classification of 56%. Specifically, the model accurately predicts PNEO failures 75% of the time, and successful completions only 55.7% of the time. The COMPALL3 model's predictive failures may be attributed to time lapse between graduating the U.S. Naval Academy and taking the Engineer's exam, which can be up to five years. The predictive abilities of the Academy-related independent variables is lessened because of confounds which develop during the time lapse. Therefore, the study suggests that Academy-related factors have difficulty predicting fleet performance measures.

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a summary of the conclusions formed during the study data analysis. Recommendations are also provided for further research into both officer performance and the United States Naval Academy's service assignment procedures. Finally, a discussion related to possible policy changes resulting from this study's results is provided.

A. CONCLUSIONS

The most important finding of this study is that majors group selection is the most significant factor affecting both submarine service assignment and early technical competence at Nuclear Power School (NPS) and Naval Power Training Unit (NPTU). Engineering majors (Group 1) and mathematics/sciences majors (Group 2) consistently have a higher probability of submarine service assignment success than Group 3 majors (humanities/social sciences) for the submarine assignment (ASSIGNSU). The submarine assignment probability difference between Group 1 and Group 3 majors for the average male midshipmen is 9% and for the perfect midshipmen it is 29%. These findings suggest that Naval Reactors and the USNA Submarine community are primarily recruiting midshipmen based upon their majors group. The governing reason for recruiting more technical majors was initially introduced by Admiral Rickover and his hypothesis that technical majors make better naval officers. Statistical analysis of the successful completion of NPS and NPTU (COMP2) model would indicate that this technical major emphasis is warranted because Group 1 and 2 midshipmen have a higher probability of success completing both NPS and NPTU. However, the Group 3 majors, who make it through NPS and NPTU, actually have a higher probability of passing the Prospective Nuclear Engineer Officer (PNEO) examination then other majors groups. These findings further suggest that recruiting high-performing, Group 3 midshipmen can be just as beneficial as Group 1 and 2 midshipmen if proper selection criteria are used. The proper selection criteria for Group 3 majors would eliminate the unnecessarily high percentage (16.7%) of Group 3 officers that failed out of NPS or NPTU. The benefits to the submarine community would be an expanded pool of talented midshipmen, who could perform successfully during all technical aspects of submarine service.

Next, technical courses quality point rating (TECH_QPR), or the cumulative grades of the science and engineering courses essentially common to all majors, is a significant predictor of submarine service assignment and NPS/NPTU success. Once again, Naval Reactors' belief in the "Rickover hypothesis" can explain the behavioral relationship between TECH_QPR and being selected for submarine service. The relationship with NPS/NPTU success is due to the fact that Group 1 and 2 officers receive constant technical training during their Academy careers. Group 1 and 2 officers enter power school shortly after graduation with the technical knowledge and ability required to complete the curriculum. Group 3 majors need a longer time to acquaint themselves with technical matters and are essentially "catching up" to their peers. There is a "pre-school" program at NPS designed to improve potentially weak students prior to the official start of classes. Students are either assigned to or can request this program which focuses on the principles of mathematics, physics, and thermodynamics. The study's findings would suggest that the "pre-school" program could be improved to target other traditionally weak areas for Group 3 majors.

It appears that the two job performance theories, i.e., tacit knowledge and general knowledge are equally as important to the technical competence of a submarine junior officer. During the initial training phase at NPS, general knowledge is more important because this program is seeking to build upon the officer's technical knowledge. The goal is to provide officers with sufficient knowledge required to understand the complexities of nuclear power. The next training phase at NPTU, requires officers to demonstrate their proficiency while standing actual watches. In order to be successful during this phase, officers need primarily tacit knowledge because they must be able to respond to simulated casualties and other watchstanding conditions. Often times the proper responses are not clearly delineated in the operating manuals, but require the officer to figure out the best courses of action using all available indications. The final phase, the Prospective Nuclear Engineer Officer (PNEO) exam is the culmination of a junior officer's nuclear training and it relies equally on both tacit and general knowledge. In order to become an Engineer, officers acquire additional knowledge through intensive study programs and demonstrate their competency levels with oral and written interviews. In summary, a submarine junior officer must have sufficient quantities of both tacit and general knowledge to be successful during the technical training phases.

Only four of the 291 officers who graduated the Naval Academy and were eligible for the PNEO exam failed the exam. Passing PNEO is essential for a submarine junior officer to continue his career in the submarine force. These findings suggest that the strong technical background provided by the Academy's core curriculum and the fleet's effective training and qualification program provide USNA graduates with the ability to do well during the PNEO exam. Therefore, both tacit knowledge (qualifying and standing watch at NPTU and on a submarine) and general knowledge (academic knowledge gained from the Academy core curriculum and Nuclear Power School) are equally important to the development of a submarine junior officer's technical competence.

Surprisingly, the Technical Interest Scale (TIS) score, which is an initial measure of an USNA applicant's interest in pursuing technical majors and careers, is not a statistically significant predictor of submarine service assignment. The initial assumption is that TIS scores would be positively correlated with choosing a career in the highly technical submarine service. One could reasonably assume that a submarine officer would need to have a fair amount of technical interest in order to be successful. There are a couple of possible scenarios which may have caused the surprising findings. First, the Strong Inventory Interest (SII) survey, which is used to calculate the TIS, either does not accurately reflect an applicant's technical interest or the USNA Admissions Board is interpreting the SII results incorrectly. As a result, an applicant's true technical interest is not truly measured. Another possibility is that a midshipman's technical interest changes while attending the Academy. Midshipmen are exposed to different technical courses, training programs, and opinions about technical communities. All of these experiences are bound to change their initial impressions about different technical fields of study and communities. As a result, the TIS score taken during the application process is no longer an accurate indicator of the midshipman's current technical interests that predict submarine service selection.

Lastly, it is observed that pre-Academy and Academy-related independent variables gradually lose their predictive abilities on a submarine officer's technical competence as the officer's career advances. One reason for this loss is that as more time elapses between when the pre-Academy and Academy variables were measured and the predicted outcome occurs, more confounds are introduced into the model. Many factors, such as a submarine's onboard training and qualification programs or the submarine's patrol schedule, may have more of an effect on an officer's chance of passing the Engineer's exam than his technical training at the Academy. Another reason is that the training and qualification programs administered by Naval Reactors and the fleet do an excellent job of preparing junior officers for careers in the highly technical submarine community. These programs are so successful that the initial advantages enjoyed by technical majors early in their submarine careers are completely dissipated by the end of the initial service obligations.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

It is thought that the findings from the study will benefit both the United States Naval Academy and the Nuclear Submarine community. However, further research related to this topic could prove to be an even greater benefit to both communities.

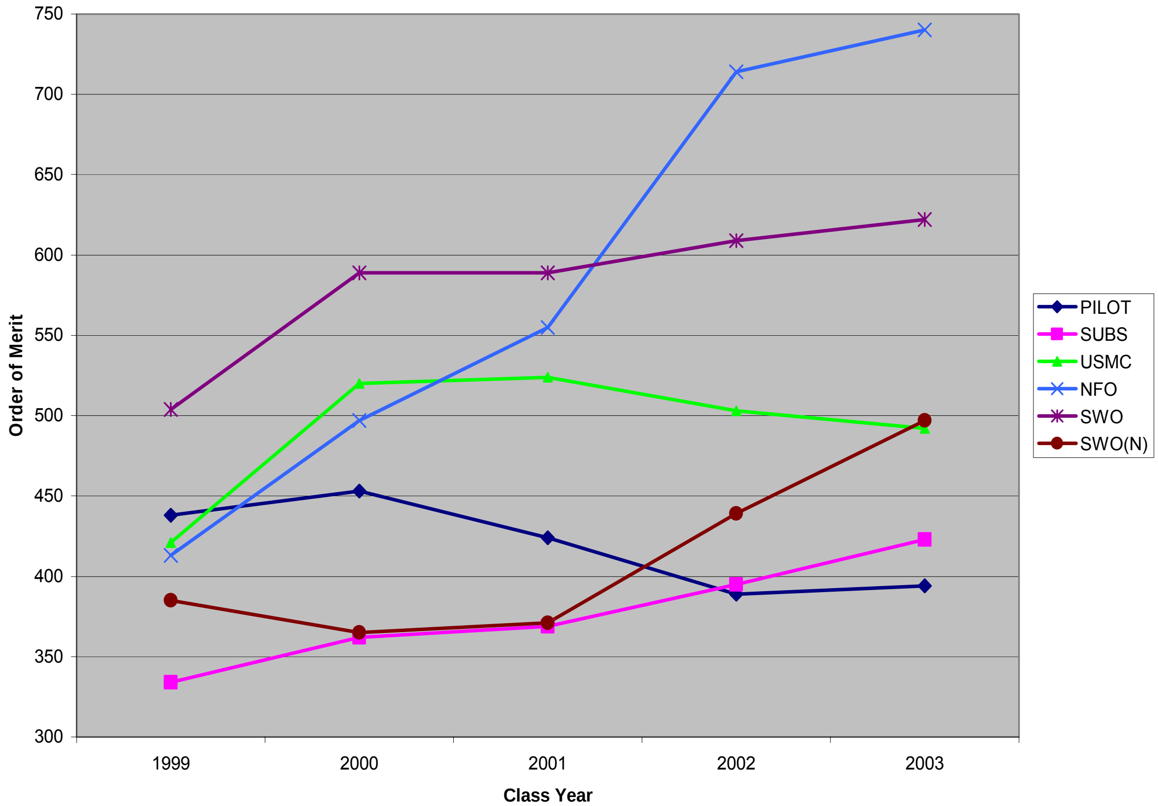
First, it is recommended that this study be replicated with the actual grades achieved by junior officers during NPS, NPTU, and the PNEO exam. The benefit would be that the research would not be limited to only dichotomous outcomes, but could evaluate a range of officer performance. For instance, the researcher could differentiate between those officers that passed all three programs with 4.0 grade point averages and those who only received 2.0 grade point averages. Also, the researcher could identify the exact courses in Nuclear Power School in which Group 3 majors had trouble.

Next, the Naval Academy recently introduced a new program designed to assist midshipmen who are assigned submarine service. This program is intended to provide newly commissioned officers with "refresher" training in technical subjects, such as calculus, physics, and thermodynamics. This program is modeled after the Nuclear Power School's "pre-school" programs discussed in earlier in this chapter, but occurs immediately following graduation and before attending NPS. No research has ever been conducted to evaluate the effectiveness of these "pre-school" courses. It would be valuable to learn how helpful the curriculum is to participants and if the historically weak areas are sufficiently covered.

Originally, it was intended to evaluate the effectiveness of the Academy's Order of Merit (OOM) as the primary means for service assignment. Up until the class of 1995, midshipmen who first met a specific community's entrance requirements could choose the warfare community they served based solely upon their OOM. This process was called service selection. Currently, the Academy uses a service assignment process, which still uses OOM as a primary indicator of midshipmen abilities, but also incorporates interviews with the warfare communities' representatives. No research has been done to see if the OOM's usage during either the service selection or service assignment processes has ever benefited the Navy or the individual. Because OOM is an aggregate score composed of many differently-weighted measures, evaluation of it alone would be of little value. Instead, an evaluation of the measures separately could provide reveal which parts of the OOM are effective predictors of fleet performance.

In the 2002 service assignments, for the first time ever, the submarine community did not have the highest average Order of Merit among the major warfare communities. The Naval Aviation community, specifically pilots, had the highest average OOM instead of the Nuclear Submarine community. To a community that prides itself on the technical abilities of its members, this situation was a major cause for concern. The primary reason for the OOM drop appears to be the recent change in the Navy's policy on Photorefractive Keratectomy (PRK) surgery. PRK surgery allows midshipmen who were traditionally unable to fly due to poor eyesight to correct their vision and still be eligible to compete for pilot billets. Many of these midshipmen, who had high OOMs (note: the *highest* OOM is 1), would select submarines instead. Figure 8 shows the PRK effect on USNA service assignment for classes 1999 to 2003. Research into the effects of PRK surgery on the USNA service assignment process could identify which other warfare communities have been affected.

Figure 8. PRK Effect on USNA Service Assignment



The importance placed on OOM during the service assignment process is also severely questioned because the second highest contribution to the OOM calculation, i.e., the overall military performance grade, is not even a statistically significant predictor of technical competence in the submarine fleet. Therefore, the submarine fleet should not heavily weight the OOM when recruiting future submarine officers. Perhaps, submarine service assignment should be based on the overall quality point rating for technical courses taken at the Academy. Since this measure *is* a statistically significant predictor of submarine junior officer technical competence

Finally, studies into effectiveness of the RAB score as an accurate measure of a Naval Academy applicant's potential as a midshipman are not available. The RAB score is a bonus score awarded in increments of 500 points to an applicants Whole Man Multiple (WMMLT) score. The WMMLT score is a measure of an applicant's overall worthiness for acceptance into the Naval Academy. RAB is intended to raise an applicant's WMMLT score because of special circumstances that the regular WMMLT calculation does not include. Research, which determines how well RAB scores actually reflect the different areas of midshipmen performance, could be useful. The results could be used to determine which circumstances actually warrant the use of RAB scores and whether RAB scores permit the most worthy applicants to be admitted to the Naval Academy.

C. POLICY IMPLICATIONS

Listed below are the recommended policy changes for the United States Naval Academy and the submarine community as determined from this study's results.

- *Actively recruit higher quality Group 3 midshipmen for submarine service.* Every midshipman, regardless of major, must take classes covering the Naval Academy's core curriculum. The core curriculum contains a large number of technical courses designed to provide Academy graduates with a sufficient technical background. This study demonstrates that if Naval Academy Group 3 majors make it through the early part of the training pipeline, they will eventually outperform their peers. With the other warfare communities, such as Naval Aviation, competing more strongly for the top-ranking midshipmen, the submarine community must be prepared to look at non-traditional sources (i.e., non-engineering majors) for accessions. One of these non-traditional sources is Naval Academy Group 3 majors. The selection criteria outlined in this paper can be used to recruit those Group 3 midshipmen, who are most capable of technical success.

- *Brief U.S. Naval Academy midshipmen on the various ways to improve their chances of submarine selection early in their careers.* The USNA submarine community must ensure that all midshipmen who are interested in submarine service know that choosing a Group 1 major and doing well in the technical courses are the best ways to improve their chances of becoming submarine officers. In general, before midshipmen choose their academic majors, they need to understand that they may also be affecting their future service assignment possibilities.

- *Tailor "pre-school" programs to address the historical weaknesses of Group 3 majors.* Improving a weak officer's comprehension of calculus, physics, and thermodynamics is not enough to prepare them for the nuclear power training pipeline. Instead, the historically weak areas for Group 3 majors need to be identified using actual performance data (i.e., course grades) from power school and prototype. The "pre-school" curriculum could then be improved to prepare weaker students better for potential problem areas. Also, the proper USNA academic course recommendations for a Group 3 major who is interested in submarines can be made. These recommendations may include taking higher tracks of the core curriculum in order to improve the midshipman's technical abilities. In addition, those midshipmen taking higher tracks of the core curriculum should be rewarded by adding bonuses to their Order of Merits (OOMs). This would provide the incentive needed to offset the potentially lower grades received during these higher level classes.

- *Reevaluate the use of the Strong Interest test as an indicator of technical inclination.* The initial Strong Interest (SI) test taken during the application process is not a reliable indicator of midshipmen technical interests at service assignment. Some possible suggestions for this are that the SI test does not properly access technical inclination or that the Academy's Admission Board is not interpreting the SI data correctly when computing TIS scores. Perhaps, another instrument for TIS calculation would provide the USNA administration with the class' current thoughts about highly technical service communities like submarines. Then these communities would be able to predict the most likely candidates for service assignment and determine the most effective strategies to further cultivate midshipmen interest.

This study has attempted to provide the reader a sufficient insight into the United States Naval Academy's Service Assignment process and the career development of a submarine junior officer. The results of this thesis can be used to improve the USNA submarine community's recruitment efforts in order to select USNA midshipmen who are better suited for technical success during their initial tours of duty. The research strongly suggests that the submarine community's traditional emphasis on technical majors has merit, but certain Group 3 majors must be given serious consideration for submarine service assignment.

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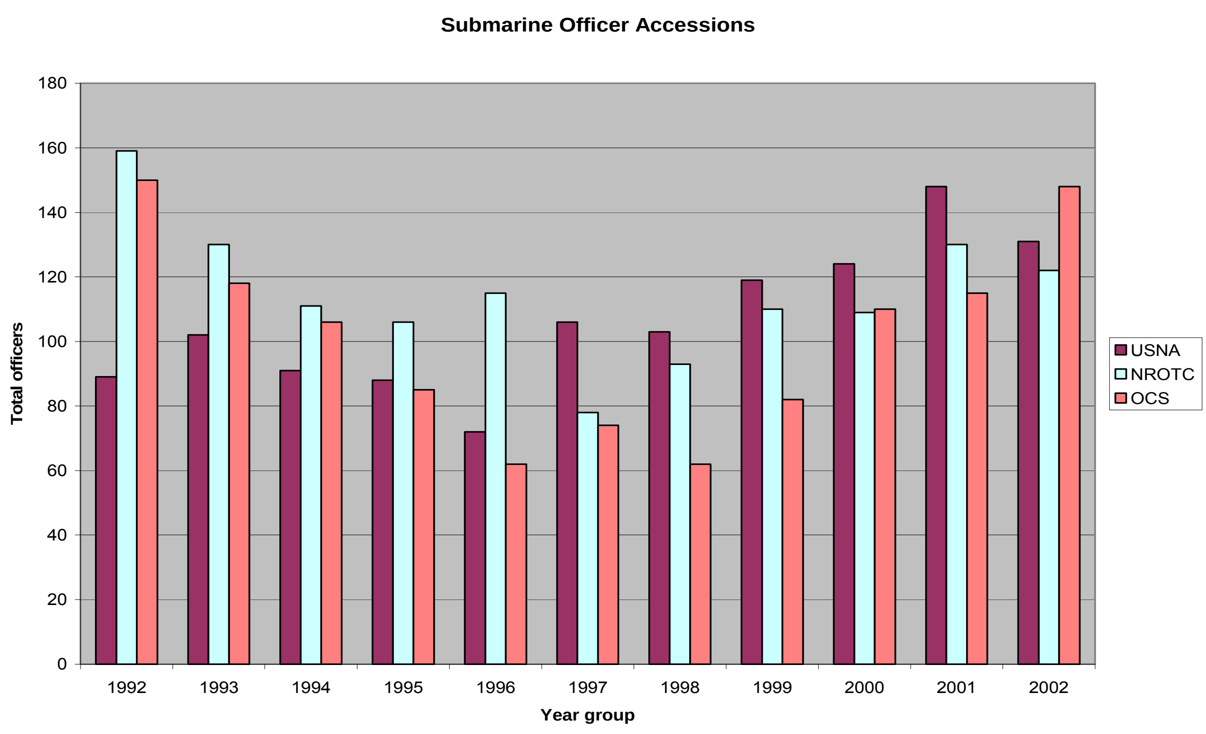
APPENDIX

Table A1- Nuclear Submarine Officers Accessions Data.[47]

Nuclear Submarine Officer Accessions Statistics

Year Group	USNA	USNA percentage	NROTC	NROTC percentage	OCS	OCS percentage	total officers
1992	89	22.4%	159	39.9%	150	37.7%	398
1993	102	29.1%	130	37.1%	118	33.7%	350
1994	91	29.5%	111	36.0%	106	34.4%	308
1995	88	31.5%	106	38.0%	85	30.5%	279
1996	72	28.9%	115	46.2%	62	24.9%	249
1997	106	41.1%	78	30.2%	74	28.7%	258
1998	103	39.9%	93	36.0%	62	24.0%	258
1999	119	38.3%	110	35.4%	82	26.4%	311
2000	124	36.2%	109	31.8%	110	32.1%	343
2001	148	37.7%	130	33.1%	115	29.3%	393
2002	131	32.7%	122	30.4%	148	36.9%	401
Total	1173	33.1%	1263	35.6%	1112	31.3%	3548

Figure A1- Submarine Officers Accessions Between 1992 and 2002.[48]



47 Cramer, Todd W. "Submarine Accessions Raw Data." E-mail to the author. 27 Apr. 2003.
48 Cramer.

Table A2- Class of 2006 Profile.[49]

Applicants and Nominees

Applicants (includes nominees)	12,333
Number of applicants with an official nomination	4,281
Nominees qualified scholastically, medically and in physical aptitude	1,770
Offers of admission	1,457
Admitted	1,214

Combined SAT & American College Testing(ACT) Program Scores

Score Ranges		
SAT (ACT)	Verbal	Math
>700(31-36)	18%	31%
600-699(26-30)	56%	55%
<600(<26)	26%	14%

Rank in High School Class

First fifth	78%
Second fifth	16%
Third fifth	4%
Fourth fifth	2%
Fifth fifth	0%

Previous College and Prep School

The Class of 2006 includes 31% (381) from college and post-high school preparatory programs which include:

> 229 from Naval Academy Preparatory School (NAPS) in Newport, R.I. (five having previously attended college)
> 33 from Nuclear Power Program (nine having previously attended college)
> 66 from private preparatory schools (seven having previously attended college and 59 from preparatory schools under the sponsorship of the U.S. Naval Academy Foundation, Inc.)
> 53 additional students have completed at least six months of study at a college or university (10 from colleges under the sponsorship of the U.S. Naval Academy Foundation, Inc.)

Military Background

125 midshipmen previously served as enlisted members of the Navy (104) or Marine Corps (21). This figure includes 12 who entered directly from Fleet Service (8 USN & 4 USMC), 33 from the Nuclear Power School and 80 from NAPS (63 USN & 17 USMC).

Geographical Distribution

[49] *USNA Admission- Class of 2006 Profile*. <http://www.usna.edu/Admissions/profile2006.htm>.

Midshipmen were admitted from 49 states in the Nation. The Class of 2006 also includes seven international students from the following countries: Cameroon, Egypt (2), Croatia, Lithuania, Taiwan, and Turkey.

School Honors and Activities

Student body/council/government president or vice president	8%
Class president or vice president	11%
School club president or vice president	26%
School publication staff	24%
National Honor Society	58%
Varsity athletics	86%
Varsity letter winner	82%
Dramatics, public speaking, debating	86%
Leader of musical group	9%
Eagle Scout/Gold Award	11%
Boys/Girls State or Nation	17%
Reserve Officer Training Programs	11%
Sea Cadets	3%

Minorities

The Class of 2006 includes 25% (299) minority midshipmen with ethnic backgrounds as follows: African Americans (78), Hispanics (121), Asian Americans (47) and Native Americans (32) and Hawaiian/Pacific Islander (21).

Women

The Class of 2006 includes 16% (192) women.

Sons and Daughters of Alumni

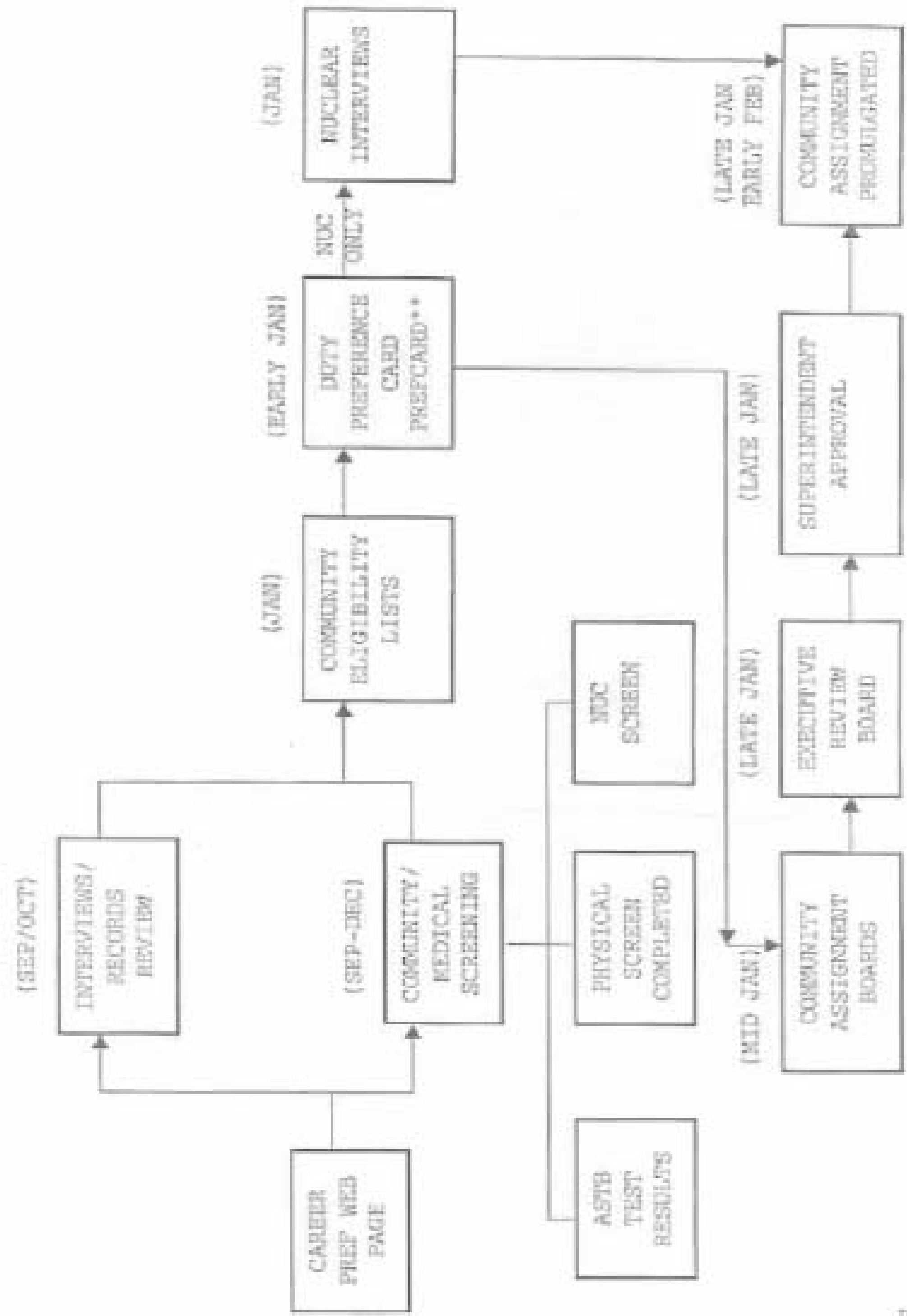
The Class of 2006 includes 44 sons and 7 daughters of Naval Academy alumni (4.2 %)

Table A3- Descriptive Statistics for USNA Classes 1994 to 1997

Descriptive Data Table for USNA classes 1994 to 1997

variable	94	94-subs	95	95-subs	96	96-subs	97	97-subs
total class size	885		898		929		932	
male mids	787		793		817		817	
female mids	98		105		112		115	
% male mids	88.9%		88.3%		87.9%		87.7%	
mids assigned subs	79	79	75	75	67	67	94	94
% of males assigned subs	10.0%		9.5%		8.2%		11.5%	
completed NNPS	76	76	69	69	66	66	88	88
completed NPTU	73	73	67	67	65	65	86	86
completed PNEO	73	73	66	66	64	64	84	84
male avg. tech qpr	2.65	3.26	2.73	3.29	2.70	3.25	2.73	3.18
male avg. cum mqpr	3.26	3.44	3.33	3.52	3.21	3.35	3.18	3.27
male avg. major qpr	2.98	3.4	2.97	3.40	2.97	3.31	2.98	3.26
male avg.OOM	448.7	201.1	451.7	210.90	477.3	260.70	481.1	317.40
male avg. CIS	500.03	511.76	499.33	511.31	510.4	528.46	507.5	511.19
male avg. TIS	495.9	505.37	499.47	533.4	506.06	507.62	507	501.86
male avg. SATM	658.13	701.65	661.25	696.13	662.28	698.87	663.5	694.15
male avg. SATV	638.98	664.3	637.1	676.8	633.66	657.46	635.6	656.28
male avg. RAB500	3.35	1.81	3.28	1.17	2.96	1.82	2.67	1.78
males in grp 1	293	59	330	53	365	52	333	52
passed NNPS		56		51		52		50
passed NPTU		54		50		52		49
passed PNEO		54		49		51		49
males in grp 2	206	16	183	12	183	12	191	29
passed NNPS		16		11		12		26
passed NPTU		15		10		11		25
passed PNEO		15		10		11		23
males in grp 3	288	4	280	10	269	3	293	13
passed NNPS		4		7		2		12
passed NPTU		4		7		2		12
passed PNEO		4		7		2		12
male grp1 percent	37.2%	74.7%	41.6%	70.7%	44.7%	77.6%	40.8%	55.3%
male grp2 percent	26.2%	20.3%	23.1%	16.0%	22.4%	17.9%	23.4%	30.9%
male grp3 percent	36.6%	5.1%	35.3%	13.3%	32.9%	4.5%	35.9%	13.8%

Table A4- USNA Service Assignment Flow Chart[50]



[50] COMDTMIDNINST 1301.1B- Service Assignment Procedure. Encl (1).

Table A5- Service Assignment Sample Interview Questions.[51]

1. Explain why you feel you have the qualifications to be an officer in the Navy or Marine Corps?

2. Explain why you chose this particular community over the others?

3. What specific actions have you taken over the last three years to prepare yourself to be a (warfare specific/service) officer?

4. Describe your participation in non-academic pursuits: sports, extracurricular activities (ECAs), community involvement, striper billets, etc. and how you believe they have prepared you to be an officer in the Navy and Marine Corps.

5. What do you anticipate will be the toughest leadership challenge when you first enter the fleet?

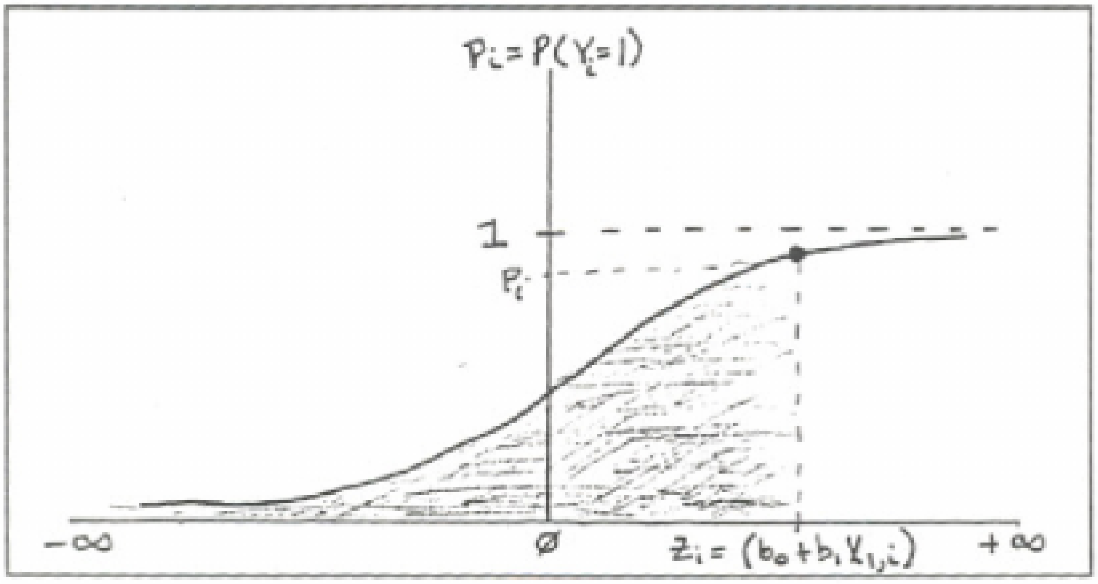
6. How did your summer cruises or other training help to prepare you?

7. Please discuss your performance record while at USNA.

8. Describe the career path you anticipate for your preferred service/community. What do you expect your initial and subsequent assignments will involve?

[51] COMDTMIDNINST 1301.1B- Service Assignment Procedure. Encl (2).

9. **Figure A2- LOGIT Cumulative Density Function**[52]



[52] Bowman, Dichotomous, 6.

Table A6 - Complete LOGIT Calculations for Service Assignment Model (Academy variables only

SUBMARINE SERVICE ASSIGNMENT (ASSIGNSU) MODEL LOGIT SPECIFICATIONS (Academy Variables only):					
VARIABLE	**XBAR**	**LOGIT**	**X*LOGIT**	**MARGINAL LOGIT*P(1-P)**	**Z=S(X*LOGIT)** -2.37291
Constant	1.000	-6.598	-6.598	-0.514593293	**P=1/(1+e^-Z)**
GROUP 1	0.704	1.599	1.125696	0.124709711	**0.08526**
GROUP 2	0.210	0.911	0.19131	0.071050999	
Class of 94	0.245	-0.158	-0.03871	-0.012322786	
Class of 95	0.247	-0.030	-0.00741	-0.002339769	
Class of 96	0.254	-0.464	-0.117856	-0.036188434	
TECH_QPR	2.700	1.227	3.3129	0.09569657	
CUM_MQPR	3.240	-0.672	-2.17728	-0.052410836	
MAJOR_QP	2.970	0.652	1.93644	0.050850989	

Table A7 - Complete LOGIT Calculations for Service Assignment Model (Pre-Academy variables) only.

SUBMARINE SERVICE ASSIGNMENT (ASSIGNSU) MODEL LOGIT SPECIFICATIONS (Pre-Academy Variables only):					
VARIABLE	**XBAR**	**LOGIT**	**X*LOGIT**	**MARGINAL LOGIT*P(1-P)**	**Z=S(X*LOGIT)** -2.627017
Constant	1.000	-10.727	-10.727	-0.674453029	**P=1/(1+e^-Z)**
SATM	661.330	0.008	5.29064	0.000502995	**0.067419763**
SATV	636.320	0.004	2.54528	0.000251497	
RAB500	3.060	-0.061	-0.18666	-0.003835335	
CIS	504.380	0.001	0.50438	6.28743E-05	
TIS	502.180	0.000	0	0	
Class of 94	0.245	-0.084	-0.02058	-0.005281444	
Class of 95	0.247	0.117	0.028899	0.007356298	
Class of 96	0.254	-0.244	-0.061976	-0.015341339	

Table A8 - Complete LOGIT Calculations for Successful Completion of NPS and NPTU Model

SUCCESSFUL COMPLETION OF NPS AND NPTU (COMP2) MODEL LOGIT SPECIFICATIONS (Academy Variables only):					
VARIABLE	**XBAR**	**LOGIT**	**X*LOGIT**	**MARGINAL LOGIT*P(1-P)**	**Z=S(X*LOGIT)** 2.88045
Constant	1	-3.005	-3.005	-0.151168561	**P=1/(1+e^-Z)**
GROUP 1	0.686	1.179	0.808794	0.059310394	**0.94687**
GROUP 2	0.219	0.146	0.031974	0.007344629	
Class of 94	0.251	-0.31	-0.07781	-0.01559476	
Class of 95	0.238	0.258	0.061404	0.012978865	
Class of 96	0.213	1.054	0.224502	0.053022184	
TECH_QPR	3.24	1.49	4.8276	0.074955459	
CUM_MQPR	3.39	-0.221	-0.74919	-0.011117555	
MAJOR_QP	3.34	0.227	0.75818	0.011419389	

Table A9 - Complete LOGIT Calculations for Successful Completion of NPS, NPTU, and PNEO Model

SUCCESSFUL COMPLETION OF NPS, NPTU, AND PNEO (COMPALL3) MODEL LOGIT SPECIFICATIONS (Academy Variables only):					
VARIABLE	**XBAR**	**LOGIT**	**X*LOGIT**	**MARGINAL LOGIT*P(1-P)**	**Z=S(X*LOGIT)** 7.33617
Constant	1	13.339	13.339	0.008679628	**P=1/(1+e^-Z)**
GROUP 1	0.704	-7.299	-5.138496	-0.004749427	**0.99935**
GROUP 2	0.21	-8.745	-1.83645	-0.005690333	
Class of 94	0.251	-8.683	-2.179433	-0.00564999	
Class of 95	0.23	-8.175	-1.88025	-0.005319436	
Class of 96	0.223	-8.275	-1.845325	-0.005384506	
TECH_QPR	3.26	-1.518	-4.94868	-0.000987756	
CUM_MQPR	3.39	2.185	7.40715	0.00142177	
MAJOR_QP	3.35	1.319	4.41865	0.000858267	

Table A10 - LOGIT Results for All Models Using Both pre-Academy and Academy Variables Simultaneously

	Submarine Service Assignment Model ASSIGNSU			Successful Completion of NPS and NPTU Model COMP2			Successful Completion of NPS/NPTU/PNEO Model COMPALL3		
independent variables	**LOGIT**	**Signif.**	**M.E.**	**LOGIT**	**Signif.**	**M.E.**	**LOGIT**	**Signif.**	**M.E.**
constant	**-7.955**	**0.000**	**-0.4197**	-2.903	0.575	-0.1532	13.339	0.888	0.7038
SAT Math	0.002	0.252	0.0001	-0.001	0.885	-0.0001	0.008	0.545	0.0004
SAT Verbal	**0.003**	**0.008**	**0.0002**	0.002	0.641	0.0001	-0.007	0.539	-0.0004
RAB500	-0.023	0.318	-0.0012	0.071	0.503	0.0037	-0.318	0.092	-0.0168
CIS score	0.000	0.497	0.0000	0.001	0.610	0.0001	0.006	0.298	0.0003
TIS score	**-0.002**	**0.016**	**0.0001**	-0.003	0.259	-0.0002	-0.004	0.542	-0.0002
Engineering Majors	**1.741**	**0.000**	**0.0920**	**1.612**	**0.022**	**0.0851**	-7.299	0.929	-0.3851
Math/Sciences Majors	**1.023**	**0.000**	**0.0540**	0.544	0.460	0.0287	-8.745	0.916	-0.4614
Class of 1994	-0.137	0.457	-0.0072	-0.199	0.752	-0.0105	-8.683	0.844	-0.4581
Class of 1995	-0.008	0.966	-0.0004	0.211	0.731	0.0111	-8.175	0.853	-0.4313
Class of 1996	**-0.453**	**0.017**	**-0.0239**	1.084	0.215	0.0572	-8.275	0.852	-0.4366
Technical QPR	**1.140**	**0.000**	**0.0601**	**1.485**	**0.014**	**0.0784**	-1.518	0.413	-0.0801
Cum. Military QPR	**-0.801**	**0.011**	**-0.0423**	-0.316	0.780	-0.0167	2.185	0.388	0.1153
Major QPR	**0.566**	**0.003**	**0.0299**	0.158	0.782	0.0084	1.319	0.375	0.0696

***- bold indicates significant**

Table A11 - Summary Data Results for All Models Using Both pre-Academy and Academy Variables Simultaneously

Summary Data	ASSIGNSU Model	COMP2 Model	COMPALL3 Model
Chi^2 model	377.179	21.586	10.999
signifcance	0.000	0.062	0.611
degrees of freedom	13	13	13
Classification			
% O correct	13.0	66.7	100.0
% 1 correct	100.0	72.9	74.6
% total correct	21.6	72.4	74.9
-2 log likelihood	1684.188	148.114	31.242
Nagelkerke R^2	0.234	0.159	0.275

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